Water Policy Reform:
Lessons from Asia and Australia

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Preface

WATER SCARCITY is a critical issue across most of the world. Burgeoning populations, coupled with industrial growth, have increased demand for water for food production and industry. Engineering solutions are invariably prohibitively expensive and therefore, in most situations, of limited application.

Irrigated agriculture is a dominant user of water resources and, as a consequence, this sector is under increasing scrutiny. Improved efficiency in the use of water available to agriculture is an imperative.

While improvements in the technical efficiency of water use are essential, there is also an urgent need to address policy issues in water resource management. At the national and basin levels, better resource allocation decision-making processes are necessary to ensure water rights are defined and protected.

At the irrigation system level, good governance is required to ensure reliable delivery of water to users, appropriate scheduling of supply, and the maintenance of infrastructure. Pricing of water to ensure cost recovery of delivery services is on the reform agenda of many developing country governments.

These are the proceedings of a workshop that brought together researchers working in the area of water resource management. The aim was to explore possible synergies in water policy research focusing on experiences with water policy reform in different countries. The workshop provided a forum to discuss current research in the areas of institutional economics, water pricing and system modelling to assist in the identification of priorities for water policy research in ACIAR's partner countries.

If the workshop achieved its aims, the state-of-the-art knowledge in regard to hydro-agronomic-economic modelling approaches to water resource management in both Asia and Australia has been advanced.

ACIAR is grateful to the workshop participants for their contributions.

Donna Brennan

Water-policy Reform Issues: An Overview

Donna Brennan*

Abstract

As the demand for water rises, scarcity of water is a major concern in many countries. Policies dealing with demand management will become increasingly important as the problem of water scarcity increases. The level and efficiency of water use in agriculture is under particular scrutiny as the dominant user of the water resource. This paper presents an overview of the Australian Centre for International Agricultural Research (ACIAR) Water Policy Workshop held in Bangkok in June 2001. It provides a summary of the major discussion points, including the rules and rights governing resource use, dynamic aspects of water resource use, the means by which change can be implemented, experience with institutional reforms, and the role of research in the area.

WATER scarcity is an issue of great concern in many countries. Population and economic growth has led to rising demand for water for human consumption, food production and industrial uses, while opportunities for supply augmentation are becoming prohibitively expensive. Because irrigated agriculture is a dominant user of the water resource, the level and efficiency of water used in this sector is under increased scrutiny. Competition with other sectors may imply that less water is available for irrigated agriculture in water-scarce regions, placing increased importance on improved efficiency of water use within agriculture. Demand management policies will become increasingly important as a means of coping with increased water scarcity in the future.

The papers contained in these proceedings are the product of an ACIAR Water Policy Workshop held in Bangkok in June 2001. The aim of the workshop was to bring together researchers working in the area of water-resource management in Australia and Asia, to share their applied research experience. Numerous case studies on the management of rivers or irrigation systems were presented, and progress on policy and institutional reform was discussed. The workshop also provided a forum for discussing current research methods in the areas of institutional economics and system modelling. Some of the main themes emerging from the papers and the workshop discussion are summarised in this chapter.

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Rules and Rights Governing Resource Use

It is inherently difficult to define rights to water resources. Rules and rights governing consumptive water use need to account for the complex nature of hydrological systems. In particular, rules must account for the difficulty in actually defining the amount of water available for consumption, the difficulty in measuring water consumption, the impact of water diversions on other users, and the difficulty in excluding upstream users. Rules must also account for the fact that some uses of water provide benefits that have public good characteristics, such as environmental services. An additional complexity is that large-scale infrastructure development is often required to make water resources available. The management of this infrastructure affects the quantity and quality of water supply services provided to irrigators and other users. Yet, historically, poor governance arrangements, resistance to change, and the general difficulty in assigning private property rights to the services provided have typically burdened the management of such systems.

The 'New Institutional Economics' offers a framework for analysing the governance structures that are required for water resource use. Ray Challen describes the concept of a hierarchical set of property rights regimes, using an example of water resource management in the Murray–Darling Basin of Australia. The hierarchical structure explains the division of rules and responsibilities in a way that implies there can be co-existence of common property and private property regimes in water resource management.

The institutional economics approach emphasises the importance of transactions costs in determining the best governance structure for resource management. So-called static transactions costs are those costs associated with making decisions about resource use, including the cost of administering and enforcing rules, and the costs of making decisions about the reallocation of use rights. The allocation of decision-making power and other rules governing resource use affect these transactions costs and, according to the institutional economics theory, the best governance structure is the one that minimises these transactions costs. Dinesh Marothia applies this theoretical framework to analyse the performance of participatory management systems in India. Discussions about institutional economics and their potential application to water-resource management are also provided by Gamini Herath and Vasant Gandhi and NV Namboodiri.

Dynamic Aspects of Water Resource Use

One of the challenges of water-resource management is the dynamic nature of the water economy. Factors affecting the suitability of a certain set of institutional arrangements are subject to change, and these changes can mean that policy reform is necessary. The most important contemporary pressure for change is the rapidly increasing demand for water as an economic good. In developing countries, this is driven by increased demand for irrigation through population growth, changes in technology (the green revolution), and rising demand from other sectors, particularly urban and industrial. In Australia, the main pressures for changed demand for water have included changes within irrigated agriculture (increased opportunities in high-value perennial uses such as viticulture), and the increased demand for water for environmental services.

The maturing water economy

Historically, governments have relied on supply augmentation to meet a growing demand for water. However, in many cases, it has now become too expensive to augment water supplies, and new demand pressures need to be met by reallocating existing supplies between users. This reallocation can be achieved through administered solutions (assigning less water to agriculture) or economic solutions (providing price signals to decision-makers about the opportunity cost of water).

The determination of appropriate economic incentives for water is a bone of contention in many countries. Unfortunately, this may be partly attributed to the complexity of water-pricing issues, and public misconception, that is exacerbated by inaccurate media attention. Piyanuch Wuttisorn describes the economic concepts of water pricing, highlighting the difference between the cost of service delivery, opportunity cost (reflecting the scarcity value of water) and the social cost (reflecting external costs of water use). Much of the discussion over water pricing in Asia appears to have been over the setting of volumetric water charges aimed at covering the cost of delivery services. For example, Ashok Gulati and Sudha Narayanan refer to the deliberations that have taken place in India over water pricing. A government committee was set up to determine appropriate water fees, and recommendations were based on charging for service delivery: initially recovery of operation and maintenance costs was proposed, with phasing in of fees to cover cumulative capital expenditures in the longer term. This emphasis on service delivery charges might be attributed to the fact that the major problems facing many irrigation systems is the low level of funding for operation and maintenance, and subsequent deterioration of infrastructure.

However, as countries in Asia move towards a mature water economy and face increased pressure to manage inter-sectoral transfers of the water resource, it will be the 'scarcity' value of water that will become important. This scarcity value is likely to be considerably higher than the cost of service delivery, and unless users are aware of this value (through pricing or administered means), then overuse in particular industries will continue.

An example from the Australian irrigation industry can be used to contrast the relative importance of 'service delivery' costs and 'opportunity cost'. Fees for service delivery, which are based on full cost recovery, are around $20 per ML. The value of water traded in the market, which reflects the opportunity cost of water, is around $100 per ML. The scarcity value of water in Australia is driven by high-value opportunities within agriculture—but in the case of some Asian countries where demand pressure will come from urban and industrial sectors, the marginal value or opportunity cost of water may be even higher. Reliance on 'service charging' will not provide sufficient market signals to users of the resource, and misallocation will occur unless other administered controls are used to reallocate water between competing demands.

Technological change in water resource management

Even if demand were stagnant, technological change can have implications for the appropriateness of water management policies. For example, improvements in hydrological and related information can affect our understanding of the 'external impacts' of water consumption. An example of this is the new knowledge gained concerning the adverse consequences of irrigation in some parts of the Murray River in Australia. Anna Heaney and Stephen Beare and Shahbaz Khan discuss the problems of irrigation-induced salinity and the policy changes that may be required to solve them. Dinesh Marothia highlights the adverse consequences of irrigation developments in India, noting that in some cases the economic gains from irrigation development may not have been worth the public cost.

Similarly, Ray Challen interprets the decision of Australian governments to retain decision-making power over environmental water allocations as being the reflection of an 'option value' for anticipated future learning about water and the environment. Lin Crase et al. discuss the implications of this attenuation of private property rights to water on the operation of the water market.

Another area where technical change can affect water resource management is the technology for water supply. For example, François Molle refers to how technical change in Thailand has weakened the need for collection action at the tertiary canal level, as individual pumping has become a feasible option. Similarly, technology for water measurement can reduce the cost of enforcing devolved property rights regimes.

Implementing Change

The New Institutional Economics approach interprets the evolution of institutional arrangements as an optimal response to changing circumstances. Gamini Herath refers to the earlier work on the evolution of private property rights to land, which is often used as an example of such institutional innovation. Similarly, policy and laws concerning water resource management have gradually changed in response to changed pressures. Ray Challen discusses the historical evolution of institutional arrangements in the case of the Murray–Darling Basin in Australia. Jinxia Wang et al. discuss the evolution of property rights systems for groundwater in China that have evolved in response to increasing water scarcity, as well as responding to broader policy and institutional changes in China.

However, whether the pace of water-policy reform is at an appropriate rate or not is an open question. For example, Paul Taylor highlights the dilemma associated with a piecemeal approach to water policy and law reform, pointing out that incremental reform is the main vehicle for change even though wider reaching reforms are often needed. Indeed, inertia to change is a recurring theme in many of the papers.

Jennifer McKay, for example, discusses the problem of implementing new water laws, which are inevitably interpreted in the context of existing social norms and practices. Implementing change in water policy is a slow process. According to Ray Challen's model of the dynamic cost of institutional change, the degree of inertia in water-policy reform can be attributed to two things. These are the state that we find ourselves in, and the costs of implementing change. One of the common themes in the management of water resources throughout the world is the dominance of agriculture as a water user and the political costs of reallocating water away from this sector. The special concerns of the agriculture sector, and the problems of inherited institutional structures, were a common theme in the papers presented at the workshop.

Agriculture and politics

Agriculture is the main user of water resources in most countries. At the global level, irrigated agriculture comprised 83% of consumptive uses of water in 1995 (World Water Vision 2000). Future demand growth in other sectors, where water use generally has a higher economic value, will lead to increased pressure for reallocation away from agriculture. However, water has political importance for a number of reasons. First, water is a factor of production that is often more valuable than land, and a farmer's access to water is an important source of wealth. Water-policy reform that affects farmers access to water also affects their wealth, and where the agricultural sector has political power, such changes will be resisted. Because incumbent users' rights to water are more ambiguous than are rights to land, the process of structural adjustment where water is the scarce resource will be more politicised than it has been over the centuries where land was the scarce factor. In developing countries, the political importance of water is heightened in countries that continue to view food self-sufficiency as a policy objective.

Some examples of the political implications of water policy changes were discussed at the workshop. For example, Piyanuch Wuttisorn referred to the inertia in implementing water-pricing reforms in Thailand as being driven by concern over rural votes. Political interference was also cited as a problem in the local management of irrigation institutions. Dinesh Marothia discusses this problem in the context of participatory irrigation management initiatives in Chhattisgarh, India. François Molle also refers to political interference in the operation of water allocation systems in Thailand, and is pessimistic about the potential for water users' associations to achieve authority for effective local governance, due to lack of political support.

Inherited institutional arrangements

The fragmentation of responsibilities in the governance of water is one of the casualties of the historical evolution of institutions. Decisions regarding water allocation include decisions on water infrastructure development and maintenance, water delivery services and catchment management, and agriculture and rural development. Agencies involved in such decisions can include ministries for water resources; agriculture; electricity; public works; and the environment. Jinxia Wang et al. provide an example of fragmentation of responsibilities in the context of the Fuyang River Basin in northern China. Jennifer McKay highlights the problems of interpreting multiple and conflicting laws regarding water use, which are exacerbated when the laws are enforced by different ministries. Even within ministries, there are conflicts of interest at different levels of authority when it comes to implementing change. For example, resistance to devolution of responsibility over water resource management decisions can occur in large bureaucracies that are under threat from being downsized. Fragmentation of responsibilities also occurs on a spatial scale. For example, decisions regarding water use are often made according to administrative boundaries, despite the fact that the hydrological unit may cross a number of these administrative boundaries. As is pointed out below, one of the cornerstones of water policy reforms in recent years has been to align the boundaries of management with hydrological units.

Experience with Institutional Reforms

Many of the papers in these proceedings describe the experience with institutional reforms in Australia and Asia. Performance has clearly been mixed, both in the areas of governance and water pricing. The disappointing performance in some cases could easily be attributed to lack of political will, but could just as easily be attributed to a lack of experience with implementing water-policy principles. There is certainly a need for continued review of the implementation issues associated with introducing water-policy reforms.

This need can be reiterated by considering the cases where water-policy reform has been implemented on the basis of external financial incentives. In these cases, criteria for payment of such incentives have been 'required changes to laws'. For example, in the Australian context, much of the water-policy reform that has been undertaken by State governments in the past decade has been based on an agreement made between the States and the Commonwealth in the Council of Australian Governments. Commitments made by the States to water-policy (and other) reforms were backed up by financial incentives provided by the Commonwealth. Jennifer McKay discusses the rather cosmetic nature of some of the reforms that have been instigated in some cases, and argues that in practice they are unlikely to achieve the underlying objectives of the reforms. Similarly, SA Prathapar et al. refer to the case of the *Provincial Irrigation and Drainage Authority Act of 1997* in Pakistan that was passed through parliament in a single day to meet the deadline imposed by a donor to avoid forfeiture of a loan. Ashok Gulati and Sudha Narayanan refer to new financial incentives being offered by the central Indian Government to States that introduce water user associations. Because the implementation of water policies and laws is so difficult, it is essential that entities investing in 'financial incentives' for reform pay more attention to implementation issues if they want to effect changes 'on the ground'.

Experience with rules and regulations: institutional arrangements

The conventional wisdom on water governance is that allocation decisions are best made in the context of the hydrological unit, and water-policy reforms usually include the creation of institutions to coordinate decisions at the catchment level. The Murray–Darling Basin Commission was created for this purpose in Australia. Similarly, the creation (or empowerment) of apex coordinating bodies for river management in developing countries is a key reform being promoted by donors. Likewise, a greater emphasis is being placed on decision-making at the local catchment level. The requirement of catchment-based planning has been written into the new water acts of Australian State governments. The paper by Jason Crean and Rob Young demonstrates the role, and level of participation, of the water catchment committees in implementing water reforms in New South Wales. Sanguan Patamatamkul discusses experience with a catchment-based management approach being trialled in north-eastern Thailand.

The devolution of decision-making power to local irrigation systems is also a key focus of water-policy reform being adopted globally. Several papers in these proceedings discuss the performance of such initiatives. For example, Vasant Gandhi and NV Namboodiri provide a review of past studies on irrigation associations in India and indicates that the performance of these is mixed. In many cases, irrigation organisations are set up by the government, but fall apart once the government agency leaves. However, in other cases, farmer cooperatives have been successful and there have been marked improvements in water-use efficiency.

Madar Samad discusses some of the reasons why 'irrigation management transfer' schemes have not always been successful. One of the main issues has been that the local irrigation associations have had difficulty collecting revenue, and the gradual withdrawal of government funding has led to declining irrigation infrastructure. Ashok Gulati and Sudha Narayanan, Dinesh Marothia and François Molle make similar observations in the context of their study regions. Madar Samad points to some evidence in Sri Lanka that, when rehabilitation of groundwater systems occurred *before* transfer of management to local users, the irrigation management transfer schemes were relatively more successful. There was considerable discussion during the workshop as to why irrigation associations have been unsuccessful. Some participants highlighted that they included lack of authority of local associations in revenue-raising roles, while others cited lack of acceptance on the part of farmers. Others pointed to the top-down imposition of the organisational structures, which did not have local ownership, comparing these to traditional irrigation management systems that had evolved over centuries.

Hugh Turral and Hector Malano and Nguyen Viet Chien discuss the experience of irrigation associations in Vietnam. In that country, fee collection is generally higher than in other parts of Southeast Asia, but there is still insufficient revenue collection to provide for rehabilitation of infrastructure. Area-based fees mean that there is little incentive for individual farmers to adopt water-saving practices.

Water-pricing reforms

Opposition to water-pricing reform in developing countries is often based on arguments over equity and food security. Indeed, the question of 'inequity' (particularly that water pricing would 'tax' the poor) was raised a number of times by participants in the workshop. However, as Ashok Gulati and Sudha Narayanan point out in their discussion of subsidies in Indian irrigation, price instruments are an inefficient instrument for welfare delivery. He demonstrates the problems that have arisen through decades of subsidisation and uses 'current inequity' as an argument in favour of institutional reform. That is, existing arrangements are inequitable at the local level, because they favour irrigators at the head of the system at the expense of those at the tail. Piyanuch Wuttisorn also considers the problem of 'inequity' in her discussion on water pricing, but argues that the application efficiency principles do not necessarily need to hurt irrigators—highlighting the compensation principles embedded in tradable water markets.

François Molle's discussion on water-use efficiency highlights the complexity of the debate surrounding water policy. He refers to differences between the measurement of physical water efficiency at the farm scale and the system scale. The fact that unconsumed water ends up back in the hydrological system means that achievement of technical efficiency gains at the farm level does not affect water-use efficiency at the system scale. This argument has been a focal point for much discussion in recent years, but is somewhat misleading because it is based upon technical rather than economic efficiency. Notwithstanding externality issues, economic efficiency is about the water that is consumed rather than about return flows. Where there are large differences in the marginal value of water between different consumptive uses, large gains can be made by reallocating water from low-value to high-value uses. Unless decision-makers are given economic incentives, water will continue to be applied to less valuable uses, and users will also have less incentive to adopt water conservation practices.

As highlighted in many papers in these proceedings, the deliberation over water pricing in Asia has not led to on-the-ground changes in water management or pricing. In order to implement water pricing, it is necessary to measure volumetric consumption, and this is difficult and expensive where irrigators operate on a small scale. Participants at the workshop discussed country experiences with proxy volumetric measurement. The best example is the Warabundi allocation scheme, common in north-western India and Pakistan, which is based on allocating a time schedule for water use. Where this is strictly administered by also assessing discharge rates, it is effectively a volumetric allocation. In another example from northern Thailand, farmers pay irrigation charges according to the energy used to pump water (which varies by season). In Pakistan, the water charge for irrigators depends on the size of the pump. There are also several examples in India and China were water fees are based on the type of crop grown, although the variation in charging is not usually based on the opportunity cost of water.

The Role of Research on Water-policy Reform

Research on the performance of water-policy reform, and on policy options for improved water allocation and governance, is an urgent priority for many Asian countries, as well as for Australia. Water policy is inherently difficult, and involves trade-offs between the benefits and costs of alternative institutional arrangements. These arrangements will continue to need revision as demand pressures and technologies change, and as social experience with water-management arrangements progresses. Research on the implementation of water-policy reforms, and exchange of experience on these reforms between researchers of different countries, will provide important lessons for policy-makers.

It must be acknowledged that the benefits of changes in water-resource management are difficult to measure because of the common property nature of water resources. As highlighted above, the welfare and political implications of reallocating water between users are key considerations in the process of water reform. These are particularly important in the case of competing inter-sectoral demands, or in large river basins that cross jurisdictions. System modelling provides a tool for assessing allocation rules, and for clarifying the importance of third-party effects in water use. These tools have been used widely in Australia to support debate surrounding water-policy reforms. For example, they were used extensively to examine the impact of water-charging and water-trading rules in the lower Murray–Darling Basin. Papers by Shahbaz Khan, Anna Heaney and Stephen Beare, and Jason Crean et al. illustrate the use of these models in the Australian context. These modelling approaches could be used to inform the policy debates in Asia regarding the impact of alternative water allocation and other policy reforms. Such research effort, together with continuous feedback on progress with institutional reforms in water management, will make an important contribution to the problem of water-resource management in Asia and Australia in years to come.

Economic Analysis of Alternative Institutional Structures for Governance of Water Use

Ray Challen*

Abstract

Evaluation of alternative institutional structures for governance of the use of water resources has in the past been incomplete and based largely on pro-market ideology rather than rigorous analysis. This is not to deny the benefits that have arisen from market-based reforms in water allocation. Rather, it is recognising that many of the issues being grappled with in relation to institutional reform relate to collective-action dilemmas and externality problems that may complicate and limit the application and effectiveness of market systems as institutions for resource allocation. In this paper, a framework is presented for addressing policy problems of institutional choice that encompasses the roles of markets, governments and other decision-making entities. Illustrative application is made to institutional reforms in the management of water resources of the Murray–Darling Rivers in Australia and the Sukhothai Province of Thailand.

A WAVE of institutional reforms for regulation of the use of water resources was initiated in the eastern States of Australia in the late 1970s as a result of increasing scarcity of water resources in the Murray–Darling Basin, and an emerging inadequacy of institutions that had been put in place in the early part of the century to facilitate development of irrigation industries.[1] By the early 1990s, the impetus for reform had become coupled with Australia's National Competition Policy and led to the establishment in 1994–1995, by an agreement of the Council of Australian Governments (COAG), of a national agenda for reform which included the following points:

- pricing of water to reflect all costs of supply and service;
- specification of resource entitlements and property rights;
- allowing and facilitating exchange or trading of water entitlements to allow water to be used in higher-value uses;
- reform of regulatory agencies and water-service utilities; and
- involving users of irrigation water in the water-reform process and in water management (National Competition Council 1997; Working Group on Water Resource Policy 1995).

Central objectives of the COAG agreement were to remove government subsidisation of water supplies and management of water resources, and to increase reliance on market mechanisms for the allocation of increasingly scarce water resources amongst alternative uses and users. These objectives were to be achieved by means including the definition of property rights to water, in accordance with a premise that such specification of rights would motivate trading in water markets and socially optimal allocations of resources. What was not made clear, however, was the exact form that these property rights should take and how such institutional change should be implemented.

In view of the lack of detail in the COAG agreement, the Federal Government's Standing Committee on Agriculture and Resource Management commissioned a study to develop a framework for property rights in water. The result was a textbook specifica-

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1. An earlier version of this paper was presented as an invited paper to the 45th annual conference of the Australian Agricultural and Resource Economics Society, Adelaide, South Australia, 23–25 January 2001.

tion of private property rights centred on establishing rights to water resources that are vested in individual water users, and recommendations to minimise impediments to trading in these rights (Standing Committee on Agriculture and Resource Management 1995). There was a presumption that conferral of private property rights to water would give rise to markets for water that were very similar to markets in land. This would, presumably, result in a self-maintaining system of resource allocation that would not only ensure that water resources were continually being re-allocated to their highest-value use, but also that there would be very little future need for government involvement in resource allocation.

However, in a slip 'twixt cup and lip, the intended property rights were modified substantially in the processes of implementation. Almost contradictory to recommendations for development of private property rights were components of a new institutional framework that would result in substantially attenuated private rights. These included: limiting the private rights to usufructory rights in water rather than ownership rights of the resource itself; variability in the actual interest conferred in the rights, such as with respect to supply reliability and constraints on transferability; restrictions on who could possess rights and participate in water-rights markets; and strong regulation of trading in water rights to account for constraints imposed by infrastructure, environmental considerations and impacts of transfers on other water-right holders. While proponents of reform were saying that strong private property rights would resolve all allocation problems, there seemed to be an unwillingness to make a full commitment to such an institutional initiative, as if the policy-makers wanted to have a foot in two ideological camps. As a consequence, the property-right reforms for water resources have fallen well short of the unattenuated rights that were the central assumption to predictions of the benefits of market allocation of water over other allocation mechanisms. Partly as a result, the re-allocations of water rights through trading have been far more limited than initially envisaged by the pro-market reformists. Private decision-making for water allocation is a long way from supplanting a historically centralised system of government regulation of water use.

The overall impression of property-right reforms for water allocation in Australia is that there is a large gap between economic analysis and practical institutional reform. It is proposed that, in a general sense, this is symptomatic of an inability to fully capture the roles of governments and markets within the analytical perspective of neoclassical economics.

In this paper, and more particularly the book from which the content of the paper has largely been drawn (Challen 2000), a conceptual model is described for framing policy problems of institutional choice. Whereas existing economic analysis of institutions tends to focus on comparative analysis of institutions as if alternative property-right institutions are mutually exclusive, the model described in this paper allows for the simultaneous existence of multiple regimes of property rights and associated institutions, organised in an institutional hierarchy. With this model, the emphasis of institutional analysis shifts from assessing the benefits of particular property-right regimes or allocation mechanisms in isolation, to considering at which level of an institutional hierarchy particular allocation decisions can best be made. Illustrative application is made to institutional reforms in management of the water resources of the Murray–Darling Basin and to the groundwater resources of Thailand's Sukhothai Province.

New Institutional Economics

No economist, regardless of how laissez faire their outlook, could seriously question the need for strong government. Markets require institutional structures established by government, including defined property rights, general protocols of contracting, and the means for policing and enforcing contracts. Indeed, to the extent that such institutions are necessary for any private trading to take place, it can be argued that no market will exist without public subsidisation of trading activities through an appropriate institutional framework.

Notwithstanding the necessity of institutional structures to support contracts for private trading, the role of institutions in resource allocation goes well beyond that of supporting markets. Vast ranges of decisions for resource allocation are made under institutional arrangements other than those providing for private decisions and market trading. Examples range from institutions for allocation decisions of international and national significance, such as with the recently topical allocation issues of international emissions of greenhouse gases, to relatively mundane decisions such as the control of pollution on a local scale and specifying permissible uses of land in urban areas. While some of these decisions are made by governments for readily recognisable reasons of market failure, for others there has never been any market, nor is it generally conceivable that market processes should be utilised for such decisions. A view of economic behaviour that fails to recognise and explain this diversity of institutions and decision-making processes is incomplete.

The 'New Institutional Economics' has given attention to the institutional structures that govern economic behaviour, including the operation of markets. The application by the new institutionalists of transaction-cost theory to the investigation of alternative institutional arrangements has been extraordinarily successful in *ex post* studies of historical institutional structures and paths of institutional change. However, there has been very little work undertaken or progress made in applying the theoretical developments and historical insight to *ex ante* analysis of proposals for institutional change. This was exemplified some years ago in the work of Ostrom (1990), where prediction of success or failure in common-property arrangements for the use of natural resources was hindered by the lack of appropriate theory for incorporating transaction costs into the analysis of particular institutional structures and determining prospects for institutional change.

What has been lacking is a forward-looking framework of institutional analysis to assess alternative institutional structures.

Concepts of Institutional Economics

A study of institutions focuses on the laws and conventions of society that either directly allocate resources, or establish the processes and constraints for agents in an economy to make allocative decisions. In studying governance of natural resources, it is useful to consider institutions of three types: property rights, entitlement systems, and mechanisms for adjusting resource allocations.

Property rights

The term 'property right' will be used in this paper as being synonymous with a decision-making power as to the way in which a resource is used. A property-right regime describes the nature of an entity holding rights of decision-making as to the use of a resource. Thus, 'private property' corresponds to a single decision-making entity such as an individual person or firm; 'common property' to a finite collective entity such as a cooperative group; 'state property' to a government entity; and 'open access' to the absence of any entity with decision-making power over a resource.

With property rights defined as decision-making powers over the disposition of a resource, it can readily be seen that for any one resource there are multiple levels of property rights—starting with broad powers of State or national governments to control the use of the resource, and ending with powers of individual resource users to make investment and production decisions for resource harvesting and exploitation. In between these extremes may be further levels of decision-making, all relating to some individual or collective entity with property rights over the resource in question.

The multiple levels of property rights can be represented as a hierarchy within which the parties with rights have their own peculiar objectives in resource management and may make fundamentally different types of decisions, all of which ultimately produce a pattern of resource use.

As a conceptual example, consider the property-right hierarchy that may exist in an ocean fishery. The highest and most general form of property right can be conceptualised as common property amongst all nations of the world and an allocation institution might be an international agreement which establishes zones of 'territorial waters' within which each nation state has exclusive rights to fish stocks. The next level in the property hierarchy may be state property, wherein a state or national government may allocate common property rights to fish stocks in particular regions to, for example, coastal communities with a historical reliance on a fishing industry. The local communities may then allocate rights to the fish stocks to individual fishermen who in turn make production decisions individually within a private property framework. This conceptual example is indicated in Table 1.

Table 1. Conceptual property-right hierarchy in an international fishery.

Scope of allocation problem	Parties to decision-making	Conceptual property-right regime	Allocation decision
Allocation of fish stocks amongst nations	Multiple national governments	Common property	Definition of territorial waters
Allocation of fish stocks amongst regional communities	National government	State property	Exclusive community rights to fishing areas
Allocation of fish stocks amongst individual fishermen	Community members or representatives	Common property	Individual transferable quota issued to fishermen
Allocation of quotas to fishing effort or sale to other fishermen	Individual fishermen	Private property	Private production and investment decisions

Note that for a single resource (in this case the fishery), there are multiple forms of property rights. It is simply nonsensical to describe the resource as being one of private property, state property or common property.

Entitlement systems

An entitlement system can be conceptualised as a quota system that provides a basis for defining shares or parts of a resource 'belonging' to the state and collective or individual entities holding property rights to that resource. Two generic types of quota can be considered: resource quota and input quota. A resource quota places a direct limit on the amount of the resource that the owner of the quota may use or consume. An example is a catch quota in a fishery that sets a quantitative limit on the amount of fish that the quota holder may harvest in a given period. A further example is an irrigation right that sets a quota on the volume of water that an irrigation farmer may utilise in a given period. An input quota restricts use of a resource by establishing limits on one or more inputs, other than the resource itself, to the production process within which the resource is utilised. Examples include the use of equipment restrictions to limit harvests in fisheries, and defining allocations of irrigation water by areas of land that may be irrigated.

Mechanisms for adjusting allocations

Procedures usually exist for allocations of resource entitlements to be changed or re-allocated amongst holders of property rights. The procedures for altering allocations may be broadly categorised as either administrative or market-based. An administrative system of re-allocation would adjust allocations by either unilateral decisions for particular circumstances, or by establishing *a priori* a set of rules that specify the circumstances under which a re-allocation of entitlements may occur and the basis for altering the allocation. Such rules may vary from highly simplistic and general 'use it or lose it' conditions, such as are part of the prior-appropriation system of water allocation in the western States of the United States of America (USA), to complex rules such as those of the Spanish irrigation huertas described by Maass and Anderson (1978) which make detailed provisions for re-allocation of water entitlements in times of drought. Market-based systems allow for trading of entitlements between resource users, often subject to constraints on who may participate in the market and the nature of transactions that may occur. Examples are individually transferable quotas in fisheries, transferable water entitlements for water resources, and tradable pollution permits for regulating water and atmospheric pollution.

Example 1: Institutions for the use of water resources in New South Wales and South Australia

The institutional structure of property rights, entitlement systems and mechanisms of changing resource allocations for part of the Murray–Darling Basin is illustrated in Figure 1.

The property-right regime at the first level of the institutional hierarchy is that of common property between the State governments of Queensland, New South Wales, Victoria and South Australia, and the

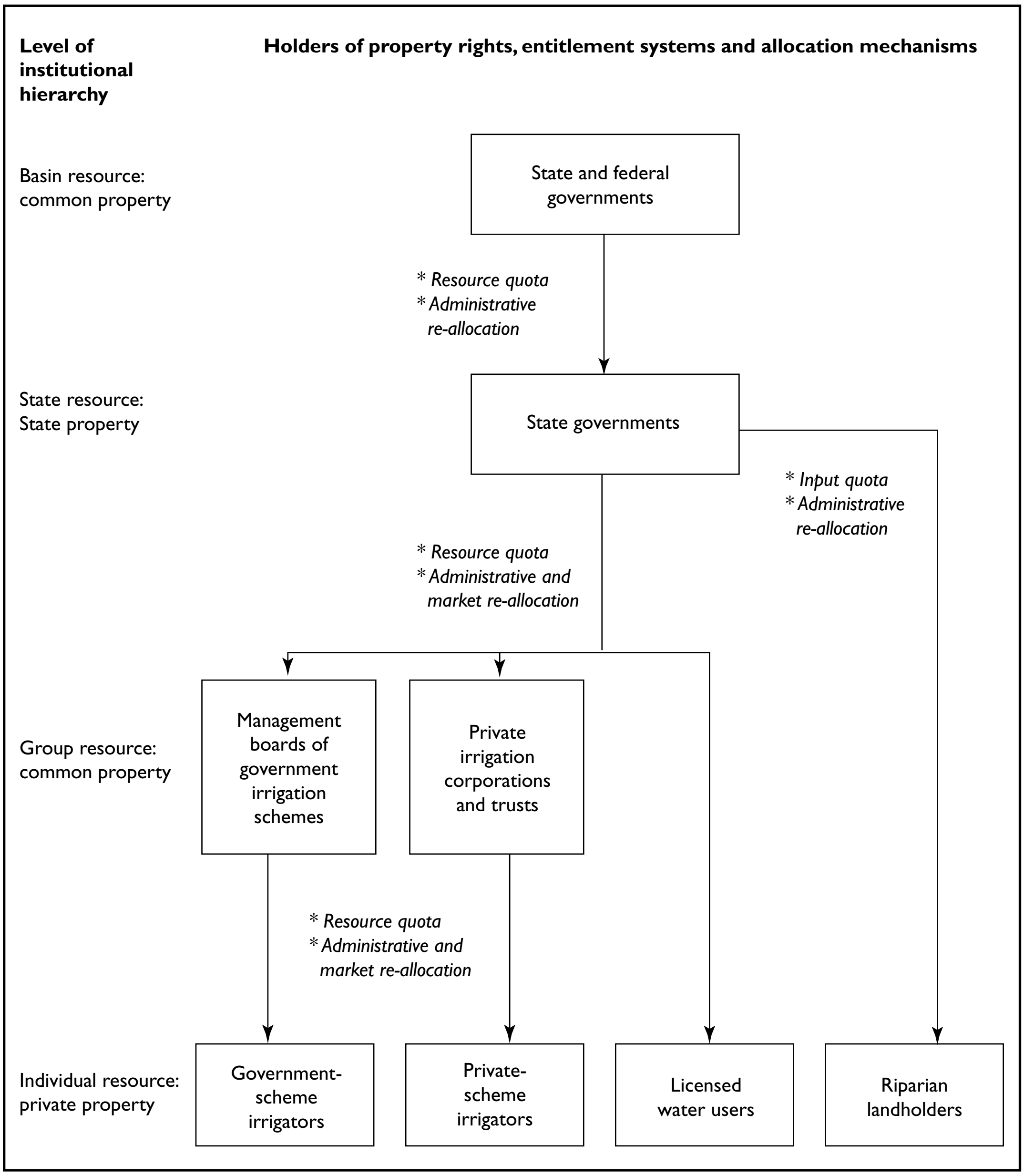

Figure 1. Institutional hierarchy for the regulation of surface-water use in the lower Murray and Riverland regions of South Australia and the Riverina and Murrumbidgee regions of New South Wales.

Commonwealth Government. Voluntary agreements between these governments (principally the Murray–Darling Basin Agreement[2]) have established rules for joint regulation and use of the resource to avoid a situation of open access whereby each State would promote use of the resource without consideration of the effects on other States.

The Murray–Darling Basin Agreement establishes a governing council comprised of ministers of each participating government and an administrative agency, the Murray–Darling Basin Commission. The principal component of the agreement is a set of rules for sharing of water resources between the three States and the means of accounting for those shares. Entitlements to the use of the water resource are all from the category of resource quotas, directly specifying an entitlement to the water resource in terms of either a volumetric entitlement or a proportional share of the available resource. The initial allocation of water entitlements between States was decided by the administrative mechanism of negotiations between the participating governments leading up to the first River Murray Waters Agreement in 1914. The allocations have since been altered by similar processes of negotiation and administrative decision.

The second level of the institutional hierarchy comprises State property. All the States of Australia have enacted legislation empowering the respective governments to administer schemes of water allocation. The legislation is similar between States and has the principal features of Crown ownership of all water resources, both surface water and groundwater, and the State governments having rights to the use, flow and control of the resources (Bartlett 1995).

New South Wales and South Australia each hold entitlements to the use of water from the River Murray, specified by the Murray–Darling Basin Agreement as described above. The States allocate water entitlements to the common-property entities of group irrigation schemes and the private property entities of individual irrigators and riparian landholders. The entitlement systems are from the categories of both resource quota (volumetric licences) and input quota (riparian rights).

Two of the types of organisations receiving licences for water diversion and use are group entities comprising collectives of individual water users, at the third level of the institutional hierarchy.

- Quasi-autonomous government irrigation agencies servicing irrigation farmers within irrigation schemes for which distribution infrastructure is owned by the State Government. These include the two agencies (Murrumbidgee Irrigation and Coleambally Irrigation) administering irrigation areas and districts of the Murrumbidgee Valley in New South Wales. Decision-making power over water use within the areas served by these organisations lies predominantly with management boards made up of irrigation farmers, although the government still holds some executive powers.
- Private agencies distributing water to individual irrigation farmers where the distribution infrastructure is collectively owned and managed by the irrigation farmers. The formal mechanisms of group association include trusts, corporations, and various other associations provided for under water-resources legislation. Decision-making power over water use within the areas served by these organisations lies with management boards or trusts made up of irrigation farmers.

The fourth and final level of the institutional hierarchy comprises a level of private property wherein individuals hold water entitlements as riparian rights (input quota) or volumetric entitlements (resource quota) granted by either the State governments or irrigation collectives.

The 'private property' water entitlements can be altered by either administrative mechanisms or by market mechanisms.

There are two general forms of administrative mechanisms for the re-allocation of water entitlements. First, the State governments and group irrigation schemes maintain powers to alter, under certain circumstances, the entitlements issued to the subordinate holders of private rights. Second, there are administrative rules in place to re-allocate entitlements in response to variations in the total water supply to all holders of entitlements.

The powers of State governments to alter water entitlements are either implicit in powers of governments to alter legislation and regulations, or are conferred by existing legislation and regulations. An example of the former is the power of State governments to alter the entitlements to water of riparian landowners. Both the South Australian and New South Wales governments have enacted legislation

2. Queensland is not a party to the Murray–Darling Basin Agreement but is a signatory to other related agreements.

that replaced common-law entitlements with circumscribed statutory rights. Similarly, the governments have powers to amend water-resources legislation to bring about other re-allocations. Powers conferred on State governments by water-resources legislation in relation to re-allocation include powers to cancel licences, to alter the volumetric water entitlements pertaining to licences, or to alter the conditions under which water is to be utilised. In practice, the power of the governments to alter licences has not been used to re-allocate water entitlements between specific licensees, although the powers have been exercised to alter licence conditions uniformly for large groups of licensees to achieve policy objectives of governments with respect to the management of water resources. Examples include the application of volumetric entitlements to all licences in both South Australia and New South Wales in the 1970s, and reducing access of New South Wales licensees to 'off-allocation' water in the late 1980s and 1990s.

The second general type of administrative mechanism for re-allocation of entitlements is that of administrative rules whereby a re-allocation occurs in response to certain changes in the natural or economic environment of water use. For both the government licensing schemes and the allocation schemes of irrigation groups, there are regulatory provisions for altering individual water entitlements in periods of low water supply. In South Australia, where the water supply is of relatively high security, the nature of adjustments to entitlements is not specified, but instead powers are conferred on the relevant government minister to alter water entitlements according to criteria of 'fairness'. These criteria would include consideration of types of crops being grown and potential economic injury to different groups of water users. The adjustments to entitlements would probably not be uniform across all water users and would thus represent a proportional re-allocation of entitlement. In New South Wales, the water supply is far less secure, and rules for adjusting entitlements in circumstances of low water supply have been incorporated into entitlement systems through the use of high-security and low-security entitlements. Under circumstances of low water supply, the high-security entitlements are satisfied before the supply of water to meet low-security entitlements. This effectively represents a proportional re-allocation to holders of high-security entitlements that occurs automatically in years of low water supply.

Water entitlements pertaining to licences issued by the State governments or entitlements within group irrigation schemes can be re-allocated by market trading. Both individual irrigators and group organisations can transfer entitlements on either a temporary or permanent basis by privately negotiated trades. In practice, the freedom to trade water entitlements is high amongst individual licence holders, but strongly attenuated for the group licence holders. The group organisations generally have rules restricting the possible transfer of entitlements away from the groups, with the objective of maintaining intensities of irrigation within the group areas and thus the economies of operating the infrastructure for water distribution.

The institutional systems for water use in New South Wales and South Australia are far more complex than can be described in simple terms as 'private property', 'state property' or 'common property'. Rather, several property-right regimes exist simultaneously, relating to different areas of decision-making on resource allocation.

The implications for policy analysis relating to institutions of water use are profound. Rather than focusing on alternative and supposedly mutually-exclusive property-right regimes, policy analysis should address, firstly, the distribution of property rights with a hierarchy of rights for the range of decisions that need to be made for allocation of a resource and, secondly, the most appropriate institutions of allocation that provide for these decisions to be implemented (entitlement systems and mechanisms of allocation and re-allocation).

Example 2: Institutions for the use of water resources in the Sukhothai Province of Thailand

The institutional structure of property rights, entitlement systems and mechanisms of changing resource allocations for groundwater resources in the Sukhothai Province of Thailand is illustrated in Figure 2.

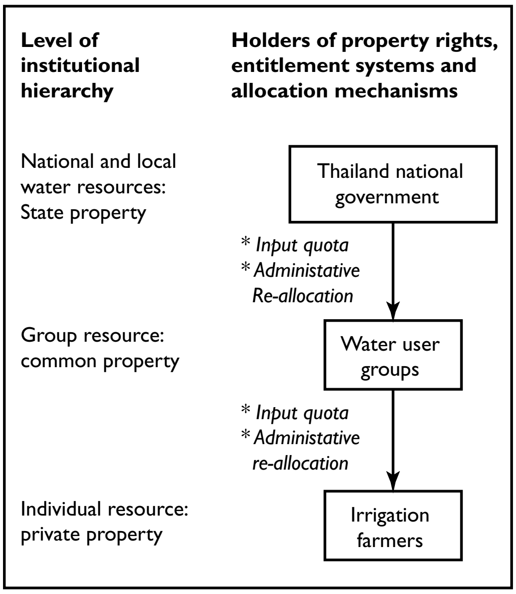

Figure 2. Institutional hierarchy for the regulation of groundwater use in the Sukhothai Province of Thailand.[3]

[3] This illustration draws on work undertaken by Wattanawit Gajaseni in 1997, during which time he was a postgraduate student in natural resources management at the University of Western Australia (Gajaseni 1997).

At the highest level of the institutional hierarchy, Thai groundwater resources are the property of the state, which exercises control through the national government agencies of the Department of Mineral Resources and the Royal Irrigation Department.

The groundwater resources of Sukothai Province are exploited largely through deep wells that are managed and operated by the Royal Irrigation Department. This department (in conjunction with other government agencies) controls and maintains the groundwater supply system, gives advice to farmers and farmer groups on water supply, and assists the next level of property-rights holders (water-user groups) to form common plans for the use of the groundwater resources.

The water-user groups comprise cooperative groups of irrigation farmers with a common-property right to over water resources. The groups form common plans for the allocation and distribution of water to individual (member) farmers according to cooperatively planned cropping patterns and associated water requirements. It is at this level of the institutional hierarchy that the water entitlements of the individual farmers are determined. Subject to the limits of the common plans, the individual farmers hold private rights (private property) to water entitlements for crops grown on private farmland.

Water entitlements for the different levels of the hierarchy are defined by input quota. Groundwater resources are allocated to water-user groups according to geographical juxtaposition of the relevant farmlands to the groundwater resources. Water-user groups allocate water entitlements to individual farmers on the basis of crop types and crop areas.

Water entitlements at all levels of the institutional hierarchy can be altered only by administrative mechanisms of decision-making within the state property structures of the relevant government agencies or the common property structures of the water-user groups.

Institutional Choice

As evident from the above discussion and examples, within each of the three subsets of institutions there are alternative institutional structures: different property-right regimes, different systems of entitlements, and different mechanisms for re-allocating entitlements. In establishing or modifying an institutional structure, decisions need to be made about the form that each of these subsets of institutions will take.

From a new institutional perspective, the central issue in examining alternative institutional structures is that of transaction costs: the costs incurred in a re-allocation of resources (a transaction) to achieve a particular allocative objective.

In the most general sense, transaction costs are the costs incurred in organising and coordinating human interaction. Coase (1960, p. 15) has described the nature of this interaction in the context of economic exchange in a market:

> In order to carry out a market transaction it is necessary to discover who it is that one wishes to deal with, to inform people that one wishes to deal and on what terms, to conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms of the contract are being observed, and so on. Transactions costs are the costs of undertaking these activities.

The above description of interaction and definition of transaction costs is centred on an individual making a trading decision in a marketplace, but not all economic decisions are made in such a manner. The description can be broadened to include a wider diversity of economic decisions. Thus, in words similar to those of Coase: in order to make *an allocative decision* it is necessary to discover who has interests in the decision; to discover who it is necessary to include in the decision-making process; to exchange information between parties to decision-making; to conduct negotiations leading up to a decision; to monitor subsequent behaviours to ensure that these are consistent with the decision; and to bear some uncertainty with respect to the outcome of the decision. Again, transaction costs are the costs of undertaking these activities.

More briefly and more generally, transaction costs have been defined as 'the costs of arranging a contract *ex ante* and monitoring and enforcing it *ex post*' (Matthews 1986); the 'costs of running the economic system' (Arrow 1969); and 'the economic equivalent of friction in physical systems' (Williamson 1985).

The scope of a transaction-cost analysis of institutional structures is the examination of institutional efficiency within a cost-effectiveness framework. This is neatly described by Williamson (1979): '[t]he overall objective of the exercise essentially comes down to this: for each abstract description of a transaction, identify the most economical governance structure—where by governance structure I refer to the institutional framework within which the integrity of a transaction is decided.'

Transaction costs for a given transaction are a function of the context of the transaction and the institutional structure.

The normative problem of institutional choice for governance of the use of a natural resource can therefore be expressed as the need to select, for a given societal/economic objective in the use of the natural resources:

- a hierarchical organisation of holders of property rights and a distribution of property rights (decision-making powers) amongst these;
- entitlement systems for different holders of property rights; and
- mechanisms by which entitlements can be altered and re-allocated, to enable the allocation decisions necessary to the achievement of the objective to minimise the costs of making these decisions.

Unfortunately, the normative policy problem of institutional change does not end with a comparative static analysis of transaction costs of certain allocative decisions.

There is also another type of transaction cost: the costs of establishing and maintaining institutions, and the costs of institutional change itself. These costs are, again, a function of the context of the institutional change (the institutional or political transaction, if you like), and the participants and processes for the change (the institutional rules for change).

There is no doubt that institutional change can be expensive. An example of institutional change in governance of river basins illustrates the costs of institutional change. The example is the development of the Murray–Darling Basin Agreement which forms the basis for interstate common-property governance of the Murray–Darling Basin.

With the growth of actual and planned diversion of water resources from the River Murray in the late nineteenth century, demand came from South Australia, and to a lesser extent from Victoria, for an agreement between the three colonies of New South Wales, South Australia and Victoria in regard to sharing of the water resources. The environment within which Victoria and South Australia were pressing for institutions of interstate water allocation had the following characteristics.

- Historical and immutable establishment of colonial (later State) boundaries that cause the River Murray Basin to occur within multiple State jurisdictions.
- Existing vesting of property in water resources in the colonies before federation in 1901, strengthened by colonial water-resources legislation vesting water resources in the Crown under control of the colonial governments.

Given this environment, there were three options for property-right regimes over the water resource of the River Murray: the *status quo* of open access of each colony/State to the resource; management as common property between the States; or legislative intervention by the emerging Commonwealth Government to override the property interests of the States. The regime that emerged was one of common property between the three States and the Commonwealth through the first River Murray Waters Agreement of 1914.

The positions of each State in respect of institutions for sharing of water resources were as follows (Clark 1971a).

- A claim by South Australia to maintain navigability in the River Murray itself and major tributaries in New South Wales, and to that end to prevent diversion by Victoria of water from non-navigable tributaries.
- A claim from Victoria, as the first colony to realise and exploit the advantages of irrigation, to a right to divert water from the upper Murray and all tributaries within its State boundaries.
- A claim by New South Wales, based on territorial rights declared by the British Imperial Parliament, to the exclusive use of waters in the River Murray above the South Australian border and in its territorial tributaries, with no regard to the claims of Victoria and South Australia.

The demands for institutions of water allocation and regulation changed over time. In the early part of the twentieth century, South Australia's claims to water shifted to a focus on irrigation as a result of the demise of river transport following the expansion of railways.

The starting-point for the development of institutions was the absence of any principles for sharing of water resources between political jurisdictions, and uncertainty of existing law, particularly on the following two issues (Clark 1983).

- An imperial law of 1855 established the New South Wales–Victoria border on the Victorian side of the River Murray. This created a *prima facie* case for New South Wales having jurisdiction over the water resources of the River Murray. In practice, however, the border and hence rights over water were imperfectly defined. Uncertainty existed over whether the bank of the River Murray on the Victorian side was part of New South Wales or Victoria, and over the location of the boundary where the river did not flow within defined banks.
- Legal uncertainty existed over applicability of common-law riparian rights to colonial/State governments.

Institutional structures for interstate resource management had therefore to be developed from scratch. A historical characteristic of the River Murray Waters Agreement and subsequently the Murray–Darling Basin Agreement has been the extreme slowness in development of agreements and institutions that address the concerns of the States, particularly the downstream State of South Australia. Principal efforts to secure supply of institutions were as follows.

- Intercolonial conferences were held in 1857, 1863 and 1865 but no agreements on rights to water and regulation of the watercourses were reached (Clark 1971a).
- An 1885 agreement between New South Wales and Victoria that entitled each of the two colonies to make full use of waters of tributaries in each respective colony and entitled each State to a half-share in the waters of the Murray—an agreement from which South Australia was excluded (Clark 1971a).
- Convention debates for federation in the 1890s, and consideration of a prospective role for the Commonwealth (Clark 1983).
- Development of a negotiated agreement between the three States in the early twentieth century.

Access to water of the River Murray by New South Wales, Victoria and South Australia was one of the principal inter-colonial issues that gave impetus to the federation movement in the late eighteenth century, and federation was seen, particularly by the downstream State of South Australia, as a means of resolving the issue (Clark 1983). The Commonwealth Government did not, however, gain legislative powers over the river and the allocation of water. To the contrary, a clause of the Australian constitution (section 100) limited the right of the Commonwealth to enact legislation which removed power for water regulation from the States: 'The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation'. The absence of Commonwealth intervention has been interpreted as being a result of an already established Australian political paradigm of State parochialism and jealous guarding of sovereignty by New South Wales and Victoria (Crabb 1988, p. 2).

In the absence of overriding Commonwealth legislation, the options for property rights to the water resources of the Murray–Darling Basin were either a regime of common property brought about by voluntary agreement, or a condition of open access. In 1902, some movement was made towards developing an agreement, when the three States participated in a joint Royal Commission investigating the legal basis of claim to water (Clark 1971a). Interstate negotiations continued after this, but it was not until 1914 that the River Murray Waters Agreement was created. Development of the agreement after 1914 to address concerns over water quality and other issues continued to be slow and it was not until the 1980s that amendments to the agreement directly addressed issues of water quality and environment quality (Crabb 1988, p. 3).

The slow rate of institutional development suggests a problem of institutional supply arising from a lack of incentives for the negotiating States to invest in and commit to institutional change. There are three general factors that may have contributed to this situation through creating high transition costs of institutional change.

- The absence of any overlying institutions to State property in the water, such as Commonwealth (national) water law, that could compel or impose an agreement, and consequently the need for any agreement to be created by voluntary and unanimous decision of the three State governments. As a result, development of institutions for collective action between the States was hampered by collective-action dilemmas and commitment problems.
- A lack of institutional precedents for agreements over inter-jurisdictional rights to water resources. Successive versions of the River Murray Waters Agreement and the subsequent Murray–Darling Basin Agreement have generally been abreast with, or more advanced than, similar interstate agreements elsewhere in the world, such as in Canada and the USA (Crabb 1988, p. 21). As a consequence, institutions have generally had to be designed from scratch and initial negotiating positions of the States may have been more divergent than would have been the case if precedents had been available.
- The benefits and costs of implementing new institutions were unevenly distributed between the three States. While the development of institutions for management of the Murray–Darling Basin may have improved the welfare of the three States in total, the benefits have accrued disproportionately to the downstream State of South Australia and opportunity costs disproportionately to upstream States of New South Wales and Victoria.

The three factors of a lack of supporting institutions, a lack of institutional precedents and uneven distribution of costs and benefits have been highlighted as impediments to institutional change in many other situations of common property (Ostrom 1990).

Given these impediments to development of institutions, the history of development of the Murray–Darling Basin Agreement can be seen as a process constrained by existing institutions of State sovereignty, and where advances in institutional development occurred in response to 'threats' to the upstream States that altered the envisaged costs and benefits of institutional change and provided a basis for negotiation. After the upstream States of New South Wales and Victoria held out against formalising property rights to water of the River Murray until the early 1900s, there were two possible factors that provided impetus for a political agreement. First, in 1904 the Prime Minister suggested that the Commonwealth might act when the States were asked whether they would hand over control of the River Murray to the Commonwealth Government (Clark 1983). Second, South Australia commenced preparations for litigation against New South Wales and Victoria with regard to maintaining the navigability of the river (Clark 1983). The result was negotiation for a political solution that led to proposals for water sharing in 1906 and eventually to the first River Murray Waters Agreement in 1914 and the associated rules for water allocation between the three States (Clark 1971b, 1983). Further threats of litigation by South Australia in the 1950s and 1970s provided the impetus for the 1959 and 1981 amendments to the agreement that provided South Australia with a greater share of water and introduced powers for the interstate management agency (then the River Murray Commission and subsequently the Murray–Darling Basin Commission) to manage water quality in the South Australian section of the river (Clark 1983).

Further amendments to the interstate agreement were made in 1982, 1987, 1990 and 1992. The amendments broadened the scope of the agreement to include the New South Wales section of the Darling River Basin and to widen the charter of the interstate managing agency with respect to water quality and management of land and environmental resources.

Unlike the 1959 and 1981 amendments, however, it appears that the later amendments were made at least partly in response to emerging 'moral standards' in management of river basins (Crabb 1988, pp. 1–2). In terms of the model of institutional change, this can be considered as a change in tastes and preferences of economic and political agents that drives institutional change. Crabb (1988) refers to the following changes in the moral standards underlying institutional change: principles of the river basin being the basic hydrological unit of management; of no State having claim to exclusive access to waters of an interstate river basin; of individual States being entitled to reasonable and equitable participation in control and apportionment of the resource; of protection and non-abuse of the resource; and acknowledging interrelationships of the water resource and other natural resources.

The factors contributing to the development and continuance of the Murray–Darling Basin Agreement can thus be summarised and interpreted in terms of transaction costs as follows.

- The development of institutions of interstate water allocation was hampered by high transition costs arising from collective-action dilemmas and the absence of institutional precedents.
- Institutions of common property between the three States and the Commonwealth were only developed once the threats of litigation by South Australia and intervention by the Commonwealth made institutional change inevitable. The path of institutional change ultimately selected (interstate common property) was that commonly perceived by all the three States to have the lowest transition costs, both in terms of forming an agreement and minimising uncertainty over the institutional outcome.
- Despite development of the common-property institutions, the static transaction costs incurred in making resource allocation decisions between the States, and the transition costs in modifying the common-property institutions, have remained high and resulted in very slow processes of decision-making and institutional reform.

Several general features of institutional change can be observed from this and other instances of institutional change in the Murray–Darling Basin (Challen 2000).

Firstly, changes in institutions of water allocation have been incremental, making changes at the margin to an existing institutional structure. This is possibly a reflection of high transition costs that may be associated with large institutional reforms that substantially alter existing property-right structures.

Secondly, institutional changes involving transfers of property rights down the institutional hierarchy appear to have been much more easily and quickly achieved than changes involving transfers of property rights up the institutional hierarchy. For example, institutional change was achieved quickly and with relative ease in creating common property rights for group irrigation schemes and introducing market institutions of re-allocation of water entitlements. Both of these changes involved a transfer of property rights down the hierarchy from colonial/State governments. On the other hand, institutional change proved difficult with enactment of water-resources legislation at the turn of the century, and in the creation of institutions for interstate common-property rights. This change involved a transfer of either *de facto* or *de jure* property rights up the institutional hierarchy from State governments to an interstate common-property organisation.

It is evident from these examples that an existing institutional structure imposes constraints on institutional change. By extrapolation, any institutional changes made at the present time may constrain institutional choice in the future. It is these effects of an institutional status quo that the transaction costs of institutional change arise, both in transition costs of change and in constraints on future institutional options imposed by a current institutional change.

Turning back to the problem of institutional choice, there are thus two types of transaction cost to take into account:

- static transaction costs, being the costs of making and executing allocation decisions (transactions) within an institutional structure; and
- dynamic transaction costs, being the costs of altering an institutional structure.

A framework for policy analysis on institutional change must accommodate the objective of minimising static transaction costs, while acknowledging the constraints of dynamic transaction costs.

Policy Analysis for Institutional Change

For the institutions of water allocation in the Murray–Darling Basin, transaction costs associated with alternative institutional structures have rarely, if ever, been explicitly considered in policy analysis. Many historical institutional changes can be explained by reference to a motivation of minimising transactions costs, but policy analysts have at best given only implicit and subjective recognition to transaction costs of alternative institutional structures in achieving particular allocation objectives.

Dynamic transaction costs associated with institutional change have received some attention in the literature, principally in respect of political repercussions of decisions for institutional change where proposed changes attenuate existing property rights (Horn 1995; Dixit 1996). Horn (1995, pp. 30–31) refers to these transaction costs as 'political transaction costs' and argues that these are correlated with the degree of conflict associated with a proposed change. The existence of conflict makes it harder for legislators or other decision-makers to agree on institutional change and increases the likelihood that either the decision-makers will have to bear political repercussions for the decision or that compensation will need to be paid to the groups in society disaffected by the change.

Consideration of the dynamic transaction costs is important to policy analysis where certain conditions hold or are recognised in the analysis.

Firstly, dynamic transaction costs will only be important when it is recognised that static transaction costs are incurred in any decision-making for resource allocation and that the position in an institutional hierarchy for which the transaction costs of an allocation decision are minimised will vary according to the nature of the decision.

For example, efficient decisions for the allocation of water between irrigation activities at the farm level or between farms in an irrigation district may be made at lowest transaction cost when the decisions rest with individual farmers who can respond readily to signals of market prices, seasonal conditions etc. For other decisions, such as allocation of water to the environment, transaction costs may be minimised by having the decisions rest with State governments or at the level of common property between State governments, where the decision-making body is the Murray–Darling Basin Commission. Because the static transaction costs are positive for any institutional structure, a policy objective exists to develop new institutional structures in response to changing circumstances. Dynamic transaction costs will be incurred in the form of transition costs when changing institutions. In considering the net benefits of reduced static transaction costs under an alternative institutional structure, the transition costs of changing to that alternative structure are relevant.

Secondly, consideration of dynamic transaction costs will be important where: (i) uncertainty or ignorance exists in relation to future institutional arrangements that will need to be in place for resource allocation; and (ii) institutional change is characterised by irreversibility, meaning in a broad sense that an institutional change is more expensive to reverse than to implement. In the presence of uncertainty and irreversibilities, the value of learning about the resource system and other parameters that affect resource use will be dependent upon the costs of making appropriate changes in the institutional structure. The dual view of these costs is a value of flexibility for institutional change in response to learning.

The value that the decision-maker in the present period will attach to the opportunity of future learning is conceptually similar to the quasi-option value that has been studied in the context of irreversible decisions of environmental development versus preservation (Arrow and Fisher 1974). A reduction in future flexibility of an institutional structure may constitute a cost to society and arises where an institutional change at a given time increases the transition costs associated with institutional changes that may be required or desirable in the future. The most obvious example of this has occurred in institutional reforms associated with enactment of State water-resources legislation and creation of State property rights near the turn of the century. The resulting strong State property rights have caused very high transition costs to be incurred in the later development of the institutions of interstate common property, and have greatly impeded the management of water resources across the entire Murray–Darling Basin.

The costs associated with a loss of institutional flexibility are, in principle, a transition cost of institutional change and should be taken into account in decisions for institutional change. Institutional flexibility has an option value in instances where uncertainty exists over the future state of the resource system and future requirements for institutional change. There are prospects for learning about the future state, but the ability to respond to the learning may be limited by certain decisions at the current time.

Taking into account both the static and dynamic transaction costs, the overall policy problem is to select an institutional structure that minimises a sum of the static transaction costs, the transition costs of moving from the institutional *status quo* to the new institutional structure, and any reduction in quasi-option value arising with the new institutional structure:

$$MinC_{I_i} = c_i\left\{I_i\right\} + d_i\left\{I_0, I_i\right\} + q_i\left\{I_0, I_i\right\} \qquad (1)$$

where:

- I_0 is the existing institutional structure, possibly comprising a vector of institutional characteristics such as distributions of property rights, entitlement systems, and allocation mechanisms;
- I_i is an alternative institutional structures ($i = 1 \dots m$);
- $c_i\{I_i\}$ is a measure of the static transaction costs associated with institutional structure I_i ;
- $d_i\{I_0,I_i\}$ is a measure of the transition costs of institutional change from I_0 to I_i ; and
- $q_i\{I_0,I_i\}$ is the reduction in the quasi-option value associated with a change in institutional structure from I_0 to I_i, reflecting the dynamic transaction costs that may be incurred in changing I_i in response to learning about the future state of the world.

This formulation of the policy problem for institutional change indicates that the decision-maker may have to consider a trade-off between current benefits (reduced static transaction costs), dynamic transaction costs, and quasi-option values associated with flexibility in future institutional change. The need to make policy decisions involving trade-offs between minimising current allocation costs and maintaining flexibility in the face of uncertainty has been previously recognised, but not expressed as part of a cohesive framework for policy analysis.

Problems arise in using this formulation of the problem as a basis for policy analysis due to a lack of procedures and techniques for measuring and quantifying the different types of transaction costs and the quasi-option value. There has been a reasonable amount of both conceptual and empirical study of static transaction costs. This includes examining the effects of transaction costs on outcomes from institutional structures, and some incorporation of transaction costs into conceptual models of market institutions to indicate how these costs may affect potential allocative outcomes from these institutional arrangements. Lacking, however, are methodologies and experience in *ex ante* estimation of transaction costs in particular resource systems under alternative institutional structures. This problem was noted by Oliver Williamson almost 20 years ago in relation to transaction costs and the allocation of resources at the level of the firm: 'Further progress in the study of transaction costs awaits the identification of the critical dimensions with respect to which transaction costs differ and an examination of the economising properties of alternative institutional modes for organising transactions' (Williamson 1979). Without this, opportunities are very limited for objective prediction of allocative outcomes from alternative institutional structures, and hence for comparison of these structures.

For dynamic transaction costs, the situation is a little better in so far as political expediency often requires that economic and social impact assessments of policy initiatives recognise transition costs implicit in social and economic dislocation, and these costs are often taken into account in decision-making. Some attention has been given to considering costs of political decision-making in institutional change (Dixit 1996) but there has been little, if any, attention given to *ex ante* prediction of such costs for policy proposals relating to institutional change for the allocation of natural resources. Many political constraints and costs to political decision-makers may not be readily quantifiable.

Finally, the estimation of quasi-option values for particular institutional structures presents perhaps the greatest difficulty in quantitative policy analysis for institutional choice. Whilst dynamic–stochastic programming models may demonstrate the importance of quasi-option values in simple policy scenarios, these models are unlikely to be able to accommodate the complexities of real problems of institutional choice.

Given these difficulties in measurement of the different parameters of the institutional choice problem, there may perhaps be some criticism of this formulation. In the words of Lancaster (1966), the formulation may be thought to 'run the danger of adding to the economist's extensive collection of non-operational concepts'. Other researchers applying the concepts of transaction costs to problems of institutional choice have been pessimistic about empirical application. Griffin (1991), for example, stated that 'because a proper analysis incorporating transaction costs has never been performed to investigate the global efficiency of a prospective institution, the applicability of … [the terms externality correction, resolution and internalisation] … is highly questionable in all but conceptual work. Moreover, the empirical difficulties to be encountered in such a rich analysis imply that the chances of ever satisfying this requirement are quite remote.'

Despite the problems of quantifying and predicting transaction costs, particularly flexibility costs as measured by quasi-option value, there is considered to be value in the formulation of the problem of institutional change as one of minimising a sum of transaction costs. Regardless of the problems of measurement, this formulation of the problem of institutional choice provides a useful conceptual framework for considering alternative institutional structures and the costs and benefits of institutional change. Indeed, the formulation provides a cohesive structure for some existing *ad hoc* procedures of policy analysis that seem to give implicit attention to all three types of transaction costs included in the problem formulation. Examples of instances where implicit attention is given to the three types of transaction costs are as follows.

In regard to static transaction costs, attention to markets as a means of improving allocation efficiency of resources can be interpreted as an often-unwitting search for allocative institutions with lower transaction costs than existing institutions of administrative allocation. Most economists have been educated to consider markets as being free of transaction costs while acknowledging the transaction costs of government decision-making arising from imperfect information. It is therefore not surprising that so many models of zero-transaction-cost markets have been put forward as a panacea for problems of resource allocation and have formed the basis for many initiatives in institutional change away from government decision-making. These policy analysts are on the right track, but perhaps not fully aware of the diversity of institutional options for allocation of natural resources and the different implications for transaction costs and efficiency of allocative decisions.

Dynamic transition costs are often given explicit recognition in policy analysis for institutional reform, particularly as the subset of costs arising from the social and economic dislocation of the people affected by proposed institutional changes.

Recognition of quasi-option values is implicit in many policy decisions based on the precautionary principle. An underlying presumption of the precautionary principle is that under conditions of uncertainty and irreversibility, it may be better to take a cautious stance in resource allocation for the time being, with the possibility of revising that stance at some later date as new information becomes available. A preservation of quasi-option value is implicit in preferences for gradual institutional change. As indicated by Dorfman (1981): 'one motivation, surely, for the prevalence of introducing regulations or dismantling them by graduated steps is uncertainty about the consequences of the regulatory change. It is felt to be desirable to be able to watch the adjustments as they evolve and to be able to make mid-course corrections as they are needed.' Quasi-option values have also been implicitly recognised in reform of institutions of water allocation. In Western Australia, for example, the following statement was recently made by the relevant regulatory agency in regard to institutional reform for water licences:

> Long term licences will be issued where it can be shown that there is little risk to the resource or other users. In other areas, where the risk is high, licences will be issued for shorter periods to allow periodic review. (Water and Rivers Commission 1998)

Maintaining options for government decision-making over resource allocation is implicit in a reluctance to grant long-term licences where the future state of the resource system is 'risky' and where reducing licence terms at some future time would be politically difficult.

Implications for River-basin Management

Before the 1970s, property rights to irrigation water in the Murray–Darling Basin resided largely with State governments. The governments maintained control over access of individual irrigators to water, the land areas to which water could be applied, the quantities of water that could be used, and the types and areas of crops that could be irrigated. Since the 1970s, there has been a transfer of property rights from State governments to either individual irrigators or to collectives of irrigators that have taken over ownership and/or management of the distribution infrastructure of group irrigation schemes. Principal changes to property rights and associated institutions have been as follows.

- Enhanced security of water supplies pertaining to irrigation licences as a result of embargoes on issue of further water entitlements by three of the States in the basin (New South Wales, Victoria and South Australia).
- The introduction of transferability of water entitlements, allowing water entitlements to be divided and traded, accompanied by strengthening of *de facto* and *de jure* private property rights of water users.
- Improved 'quality of title' of water entitlements with more explicit descriptions of rights in water licences. For example, specification of security of water supplies through classification of entitlements as high-security or low-security, more detailed specification of rights and duties associated with water use, and description of opportunities and constraints pertaining to water transfers and trading.
- Increased decision-making powers (stronger property rights) for private individuals in relation to water use with removal of many government controls over crop types, crop areas and times of water application.

These reforms have substantially strengthened the private property rights of irrigation farmers, corresponding to a transfer of property rights down the institutional hierarchy for water use. Further, the changes are broadly consistent with reducing the static transaction costs in allocation decisions such as the allocation of water entitlements between irrigation farmers, and determination of water allocations to different crop types. However, transfers of property rights down an institutional hierarchy can be difficult to reverse in so far as the transition costs of 'clawing back' the property rights at a later date are likely to be high. Consequently, devolution of property rights down the hierarchy may have reduced the flexibility of the institutional structure with respect to future reforms to respond to the needs of society.

This is an issue of potential importance with the Murray–Darling Basin, and no doubt with other river basins worldwide.

Environmental management is potentially more costly with stronger private property rights over water. Strong private property rights for irrigators reduce the ability for a regulatory agency to alter patterns of water use in years of low water supplies. For instance, strong private property rights may reduce the capacity of a regulatory agency to make unilateral decisions for altering water entitlements in years of low water supplies, forcing the government either to buy back entitlements to provide for environmental flows, or to bear a cost through compromised environmental objectives. Strengthening private rights of irrigators effectively transfers the risks and costs of water shortages from irrigators to the government and public.

An example of this has occurred in the 1997/98 irrigation year. Low water supplies for irrigators in the Murray region of New South Wales and the strong *de facto* property rights over water entitlements resulted in the government and public bearing the costs of water shortages through release of water from the Snowy Mountains Scheme at the expense of forgone Snowy River flows and generation of hydroelectricity. Nevertheless, the retention by State governments of substantial property rights over water use has had advantages through cost savings to the government in altering water use for the purposes of environmental management. In April 1998, the New South Wales government reduced water allocations for all irrigators in that State by 4 to 6% and in some cases by as much as 12% to provide for environmental water allocations. Compensation amounted to a $25 million package to assist farmers in the adoption of better irrigation practices. This compares with a direct cost of at least $85 million for the Murray–Darling Basin alone if the government had to buy back water entitlements from irrigation farmers.

The devolution of property rights to private farmers also reduced the flexibility of the institutional structure. It will be costly to reverse the strengthening of private rights if is later deemed desirable for greater decision-making powers (property rights) to reside at higher levels of the institutional hierarchy—communities or irrigation collectives, or governments.

These examples aside, the institutional reforms for water use in the Murray–Darling Basin since the

1970s can be considered as fairly cautious in so far as State governments have retained substantial property rights over water. The recognition of quasi-option values in maintaining a flexible institutional structure suggests that this may be quite reasonable stance despite some concerns from irrigation farmers about insecurity and uncertainty in water entitlements. The results thus add weight to such a possibility raised by Pigram et al. (1992, p. 77):

> Already, irrigators in the Murray–Darling Basin are pressing for the status of their rights to water to be specified more precisely. Security and reliability of supply are important for management decisions to ensure the continued viability of the irrigation enterprise. Security of entitlement is also important for investment decisions and to underpin a workable system for transferability. Understandably, water authorities tend to react with caution to these moves because of implied legal obligations. Moreover, such binding arrangements might inhibit necessary adjustments to water allocations, for example, to make provision for future environmental needs.

Conclusions

Institutional choice can be considered as a cost-effectiveness analysis of alternative institutional structures, attempting to minimise transaction costs of allocative decisions subject to a constraint of costs of institutional change itself.

Prospects for reductions in static transaction costs provide incentives for institutional change and determine the relative merits of alternative institutional structures. In recent reforms to institutions governing water use in irrigated agriculture in Australia and elsewhere, an emphasis on private rights and market trading can be interpreted as an effort to reduce transaction costs incurred in achieving an efficient allocation of water amongst end users, albeit not generally recognised as such.

Dynamic transaction costs constrain institutional change, particularly where proposed institutional arrangements threaten to attenuate the existing property rights and shift property rights (decision-making power) up the institutional hierarchy.

The existence of dynamic transaction costs also leads to the existence of quasi-option values, a value inhering in maintenance of a degree of institutional flexibility in the face of uncertain future requirements for institutional change.

An immediate application of this conceptual framework to institutional reform for water use in the Murray–Darling Basin and elsewhere may be in the design and selection of institutional structures to deal with threats to resource over-exploitation and environmental quality. Such institutional reform is affected by, and itself affects, the static transaction costs of making the allocation decisions necessary to achieve environmental objectives, the transition costs of institutional change, and quasi-option values associated with maintaining institutional flexibility. Many environmental impacts of irrigation have characteristics of economic externalities. Consequently, an important issue is the static transaction costs that may arise in different allocations of property rights across the multiple levels of the institutional hierarchy and decision-making by different parties in regard to water use and environmental protection. Dynamic transaction costs are important to the extent that strong property rights are currently held by private irrigators, almost in the form of a 'right to farm', and by State governments as the 'owners' of the water. These costs constrain institutional reform that may otherwise be desirable for addressing environmental problems through, for example, transferring property rights to one or more State levels where allocation decisions can take into account issues of long-term sustainability, environmental externalities and social values of water resources. Quasi-option values may be important given uncertainty about the future extent and costs of environmental degradation, future climatic change and technological change. The framework for institutional analysis outlined in this paper allows these issues to be addressed using a consistent metric.

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Transaction Costs Emanating from Policy Flexibility in Water Markets

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Abstract

Markets are playing an increasingly significant role in the allocation of water resources. The motivation for market institutions in this context has, in part, been the perceived failure of alternative modes of organisation to protect against serious environmental degradation. The benefits of water markets include their capacity to promote and smooth structural adjustment, and the congruent incentive to invest in water-saving technologies. Thus, hypothetically at least, there would appear to be some synergy between the outcomes of water markets and meeting the environmental needs of the riverine landscape.

It has also been argued that a prerequisite for an efficient water market is the non-attenuation of property rights for potential traders. And yet in many cases the state may be reluctant to strengthen individual rights in the face of considerable environmental uncertainty. Accordingly, a policy conundrum emerges from the motivation to improve the functioning of the market whilst optimising the responsiveness of the state to potential environmental crises. The question therefore arises as to the optimal level of water 'policy flexibility' to simultaneously meet the economic and environmental demands of the community.

This paper addresses these policy choices by using concepts drawn from New Institutional Economics. More specifically, we develop the notion of 'policy flexibility' as a transaction cost and analyse its impact on the permanent water market in New South Wales (NSW), the Australian State with the largest irrigation sector. Results drawn from a choice experiment reveal that 'policy flexibility' shifts the demand function for permanent entitlements to the left, thereby constraining the capacity of the NSW water market to generate surplus.

AUSTRALIAN water resources have historically been regarded as a factor of production to be harnessed in both agricultural and industrial contexts. However, the 'maturation of the water economy' (Randall 1981, p. 195), accompanied by a growing awareness of environmental degradation, has led to the emergence of a water 'management' regime. The 'management' regime requires policy-makers to broaden the scope of water policy objectives to include economic efficiency, sustainable development and ecological sustainability (Watson 1990, p. 12).

The response to the issue of water 'management' in Australia has been twofold. Firstly, an economic philosophy has been adopted to achieve a more efficient allocation amongst perceived private good users (Boddington and Synott 1989; Syme and Nancarrow 1991) by breaking the nexus between land and water titles and the establishment of markets for trading water. Secondly, a bureaucratic approach has been adopted reflecting the growing acceptance at the political and bureaucratic levels of the legitimacy of the environment to make claims on water resources (see, for example, Syme and Nancarrow 1991).

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However, set against these claims are the views of irrigators who have expressed concern about the perceived generosity of environmental allocations and seemingly unrealistic provisions for environmental risk (see, for instance, Crase and Herath 1998; Crase and Jackson, unpublished report, 1998). Of particular concern in the present context is the attenuation of private property rights that derives from a composite framework of water markets and bureaucratic or government regulation. More specifically, to account for current and future environmental demands, water has been retained as a State property right, yet individual irrigators are being simultaneously encouraged to trade the resource. Accordingly, irrigators have argued for both a strengthening of individual property rights in water and a clarification of those rights to improve the operation of economic instruments, like markets (since poorly defined property rights tend to undermine the water market and other investment activity) (see, for example, Crase et al. 2000). On the other hand, the state and environmentalists have been reluctant to reduce the attenuation of individual water property rights in the face of considerable uncertainty about the future environmental needs of riverine ecosystems.

The benefits of water markets have been widely espoused and include the implicit enticements to move the resource to its highest value use, the incentive to adopt water-saving technologies, encouragement to retire degraded lands, and even the capacity to reduce rural poverty (Doolan and Fitzpatrick 1995; Rosegrant et al. 1995; Thobani 1997). However, a growing body of literature is emerging which challenges the efficiency of water markets and emphasises the role of transaction costs and other market impediments such as the attenuation of property rights (see, for instance, Colby 1990, 1998; Crase et al. 2000). This is particularly the case in markets dealing with the permanent transfer of water rights.[1] However, in a public-policy context, measures that yield improvements to the market must be compared against constraints that may arise in the attainment of the environmental goals also assigned to water managers.

This paper draws attention to the potential conflict between economic and environmental goals in Australian water management by contextualising water policy flexibility as a transaction cost borne by participants in the water market. Accordingly, the analysis explores one dimension of the debate circumscribing stronger individual water property rights in New South Wales.

The paper itself is organised into five main parts. In the following section, we develop the theoretical framework used to measure the costs currently borne by the market as a result of the institutional *status quo* (i.e. substantially attenuated property rights for irrigators). We specifically address the role of 'policy flexibility' as a transaction cost. The next section proceeds to contextualise these transaction costs in the market framework by briefly examining the implications for buyers and sellers. We then present the results of a choice experiment conducted to create empirical estimates of the pertinent transaction costs, whilst policy implications and some brief concluding remarks are offered in the final section.

Policy Flexibility as a Transaction Cost

The origins of transaction costs

The origins of the theory of transaction costs can be traced to two influential views expressed about managed coordination and the existence of the firm. More specifically, the seminal work of Frank Knight (1921) and Ronald Coase (1937) are seen as the genesis of transaction costs economics (Demsetz 1997, p. 2). The analysis of markets and hierarchies offered by Williamson (1975) subsequently formalised the notion of transaction costs within economic theory.

The breadth of the transaction cost concept is emphasised by Williamson's (1985, p. 19) analogy with friction in real world processes. Moreover, Dahlman (1979, p. 144) contended that the concept itself has assumed the analytical status of a 'catch all' used to describe unspecified interference with the price mechanism. Given the pivotal role of transaction costs and their relationship to legislative flexibility in this research, it is necessary to formally develop the association between water property rights, transaction costs and behaviour in the permanent water market.

We begin by reviewing the notion of 'bounded rationality', attributable to Simon (1976) and later developed by Williamson (1975, 1985). Bounded rationality describes behaviour that is '...intendedly rational but only limitedly so' (Simon 1976, p. xxiv).

1. In the present context we deal only with the market for permanent transfer of entitlements.

In essence, bounded rationality emerges where information problems arise such that the actions of economic agents become constrained in some way. When accompanied by opportunism and asset specificity, these informational problems are compounded to create a form of behavioural uncertainty (Williamson 1985). Most commonly, costs arise directly from search and contract enforcement. The point is, uncertainty adds costs over and above the purchase price paid in the market and these additional costs can significantly alter the conclusions drawn from conventional market (and non-market) analyses.

Uncertainty and transaction costs

A body of literature has emerged from the concept of bounded rationality that seeks to precisely describe the information problems that form the foundation of behavioural uncertainty (see, for instance, Langlois 1984; Davidson 1988, 1991). Of particular significance in the current context is the process by which economic agents accumulate information and incorporate this into their 'boundedly rational' decisions. Davidson (1988, 1991) draws a distinction between ergodic and nonergodic processes which is useful in this regard.

Ergodicity[2] is founded on stochastic processes and yields probability data such as averages and standard deviations. Moreover, an ergodic process implies that infinite realisations of the process result in a coincidence of these data whilst finite realisations result in a convergence of data (Davidson 1988). Put differently, if all processes are ergodic '...the future is merely the reflection of the past' (Davidson 1994, p. 90). When accompanied by an assumption of rational behaviour,[3] long-run ignorance becomes implausible and transaction costs simply become the '...cost of transportation from ignorance to omniscience' (Stigler 1967, p. 291). In the presence of ergodicity then, transaction costs are generated only in the short-run. For example, Langlois and Robertson (1995, p. 29) observe that:

> [i]f the environment is genuinely one in which change is diminishing [i.e. as the nature of the ergodic process is more fully understood], then it is also one in which behaviour must become increasingly routine. And routine behaviour is easier to monitor and measure than non-routine behaviour. [...] For these reasons, one would expect transaction costs to play a small role in the long run.

However, nonergodicity arises where events are not governed by stochastic processes. In this instance, there is genuine or 'fundamental' uncertainty circumscribing events (Davidson 1991). Thus, even if economic agents are able to assimilate and process information from the past, it fails to adequately forecast the future. 'In these circumstances, sensible economic agents will not rely on available market information regarding relative frequencies, for the future is not statistically calculable from past data and is truly uncertain' (Davidson 1991, p. 133).

Dunn (1997) contends that 'cruciality' and nonergodicity are inextricably linked. Crucial decisions are those that require a level of creativeness and tend to occur in circumstances that cannot be replicated. For example, non-routine decisions that result in mistakes that cannot be corrected without significant future costs would be regarded as crucial.[4] The existence of crucial decisions suggests that not all transaction costs systematically diminish over time since the vehicle does not exist to improve on crucial decisions. A single irreversible decision by definition cannot be replicated.[5]

In sum, transaction costs can arise in either the short or long run if the information available to economic agents is imperfect or the process by which that information is assimilated is imperfect. In the case of ergodic events, the costs of search, enforcement and the like may eventually diminish, being replaced by comprehensive contracts. However, this does not imply that such costs are insignificant. In the long run, nonergodicity and the existence of crucial

2. Parry (1987) observes that the notion of ergodicity was originally borrowed by Samuelson from the literature on statistical mechanics.

3. Even bounded rationality will result in similar conclusions. Clearly, there is a close parallel between ergodicity, accompanied by bounded rationality, and the notions of adaptive and rational expectations offered by the monetarist and new classical schools of thought (see, for instance, Friedman 1953).

4. The reversibility of decisions at the institutional level has been developed by Challen (2000) and Challen and Schilizzi (unpublished paper, 1999).

5. Of course, this does not preclude learning from other irreversible decisions in similar or related fields. But since all dimensions of the decision cannot be replicated, there is at least some element of nonergodicity.

decisions can also give rise to transaction costs. In this instance, contracts will continue to be incomplete or, in the case of permanent water transfers, may simply fail to develop altogether.

Uncertainty and New South Wales water property rights

A property right can be defined as a decision-making power over a resource and its use (Challen 2000). Thus, attenuation of a property right implies that there are constraints over the power of the right holder to affect the use of the resource. In the case of New South Wales (NSW) water rights, this is reflected, in part, by the time-specific nature of entitlements, the capacity of the Minister to vary bulk access regimes, and the inability of entitlement holders to pursue compensation through the courts. Attenuation of this nature *per se* does not give rise to long-run transaction costs since comprehensive contracts can be developed (in time) that account for this attenuation. However, if the process of changing property rights is itself the subject of nonergodicity, long-run transaction costs become plausible. In addition, if the existing level of attenuation is a relatively recent phenomenon, economic agents may not have had sufficient experience with the ergodic processes to reduce short-run transaction costs to zero by forming comprehensive contracts. Both of these circumstances are evident in the case of the permanent water market in NSW.

Accordingly, it is possible to distinguish three genre of transaction costs that arise directly from the present definition of water rights in NSW. Firstly, short-run transaction costs emanate from the (ultimately) predictable reactions of government to the environmental and broader community demands on water. Such costs relate specifically to ergodic events and, under assumptions of rationality or bounded rationality, would erode over time. However, we have already observed that the present approach by legislators, that gives regard to the environment as a legitimate user of water, is a relatively recent phenomenon in NSW. The data set to accurately predict the behaviour of legislators in adjusting the attenuation of extractive right holders might, at best, be regarded as incomplete. Thus, in the short run at least, it may not be possible to develop comprehensive contracts that give account for (presumably predictable) changes to water property rights.

A second genre of transaction costs relates to any nonergodic processes pertaining to water entitlements. Altering environmental water allocations in response to the random requests of those bestowed with a transient balance of power in parliament might accord with this type of transaction cost. The propensity for political representatives to amend 'unconditional promises' after election might also be viewed in the context of nonergodic processes. Since these processes could be regarded as fundamentally uncertain, long-run transaction costs arise.

Thirdly, because the decision to sell (and buy) water permanently is crucial for most irrigators, transaction costs are likely to emerge. The manifestation of these transaction costs may well be the relative paucity of trade that has been observed in permanent water markets to date.[6]

A further interesting dimension to the policy flexibility/transaction cost relationship is the path dependency problem that arises from the current level of attenuation.[7] The previous discussion emphasises that the level of attenuation and the process of amending that level of attenuation are two different events. However, the existing level of attenuation has a direct bearing on the extent to which any future level of attenuation can be adjusted. For example, a right that is largely non-attenuated provides the holder with near exclusivity of use and decision-making power. Rights of this nature are, by their definition, difficult to amend since there are substantial costs involved in raising the levels of attenuation.[8] Non-attenuated rights would give holders access to compensation should they be adversely affected by an amendment to those rights. By way of contrast, attenuated rights can be adjusted at relatively low cost to the State since the attenuation itself may be in the form of clauses that prohibit compensation.

The point is that the level of attenuation and the capacity to amend the level of attenuation are mutually reinforcing. Non-attenuated rights are difficult to attenuate and attenuated rights give the State, or others, greater flexibility to adjust those rights. More-

6. The behaviour of irrigators in the permanent water market thus accords with Davidson's (1994, pp. 500–501) description of the role of crucial decisions.

7. This has been contextualised into a single model developed by Challen (2000) and Challen and Schilizzi (unpublished paper, 1999).

8. This is given greater attention by Challen (2000).

over, this probably forms the foundation of the Department of Land and Water Conservation's reluctance to reduce the attenuation of extractive water users. An 'adaptive approach to water resource management' is only likely to be consistent with non-attenuated rights if the state of the riverine landscape is well understood and the government is willing to use its fiscal powers to secure water for the environment. Neither of these conditions would appear to be currently met.

Extractive water users in NSW have expressed concern about the propensity for rule change and the difficulty of making planning and investment decisions in this environment (Brinsley 1998, p. 4). This suggests that economic agents in this instance may not clearly distinguish between the level of attenuation pertaining to their water rights and the processes that lead to altering that level of attenuation. Moreover, given the mutuality between these two concepts, we offer the term 'policy flexibility' to encapsulate irrigators' interpretation of their present circumstances. Policy flexibility thus describes some composite notion of behavioural uncertainty which can impose short-run transaction costs, if legislators follow an ergodic process, or long-run transaction costs if legislators adopt nonergodic processes. It also seeks to encapsulate the constraints on crucial decision-making and the relationship between the present level of attenuation and the implied future level of attenuation.

Measuring the Transaction Costs that Pertain to Policy Flexibility

Whilst the existence of transaction costs and the information problems that form their genesis have long been recognised, understanding and measuring the impact of such costs has proven problematic. In Marshallian price–quantity space, the presence of transaction costs can be depicted by a leftward displacement of the demand function. This results in fewer transactions and a lower level of market surplus than that which might be achieved by the 'notionally efficient' market. However, an interesting dilemma emerges for policy-makers contemplating reducing policy flexibility (or strengthening individual property rights) to achieve greater participation in the water market. The aforementioned description of demand implies that a more stable policy environment would invariably increase the demand for entitlements. This derives from the benefit of lower transaction costs when the purchaser knows what they are buying. However, the same conclusion does not automatically apply to potential suppliers of water entitlements.

Reducing the amount of policy flexibility adds value to existing entitlements. This arises, in part, from the mutuality between the level of attenuation of rights and the extent to which those rights are likely to be altered or changed in the future. We noted above that attenuated rights are more inclined to be amended than non-attenuated rights because they can be changed at relatively low cost to the state. It follows that attenuated rights are less valuable for two reasons. In the first instance, the attenuation itself raises the cost of current decisions pertaining to the entitlement. Secondly, the right is more likely to be amended or changed, making it more difficult (costly) for right holders to make future investment decisions.

On the basis of this observation, two differing supply responses become plausible under greater policy certainty. Firstly, a reduction in policy flexibility could result in sellers being less inclined to offer their existing entitlements for sale, since those entitlements are more valuable now. This is depicted in Marshallian space by a further leftward shift in the supply function. Secondly, and importantly in the context of the water reform agenda, suppliers may be more disposed to selling *part* of their entitlement, in the knowledge that the remaining entitlement is more secure from future policy intervention. In this case, the supply function could move rightward.

It is this second response which is implied in much of the literature that advocates the use of non-attenuated rights and water markets as a vehicle for simultaneously advancing environmental and economic goals (see, for example, Industry Commission 1992; Doolan and Fitzpatrick 1995; Rosegrant et al. 1995; Jones and Fagan, unpublished paper, 1996). Offered certainty and the incentive of trading water separately from land, irrigators are presumed to economise on the use of water by investing in water-saving technologies and amending existing irrigation practices. The resulting excess entitlements are presumably sold to higher-value users and degraded land is simultaneously retired from production. However, all of this is contingent on current entitlement holders responding to the market setting in a (boundedly) rational manner *and* on them opting to take advantage of the benefits of the water market.

It does not automatically follow that more valuable water entitlements will be used any differently to less valuable entitlements, since value in this instance is only realised upon sale. For example, sellers could choose not to sell their entitlement (or a part thereof) and continue to use water in a relatively inefficient manner, particularly where utility is derived from cultural or historical practices rather than exclusively from income. In addition, conservatism and risk aversion might bring benefits that outweigh the financial rewards attendant on the market, even with less policy flexibility. Thus, given the complexities of human behaviour in this field, it may not be possible to form definitive *a priori* expectations about the reaction of sellers to greater policy certainty.

Evidence from the Permanent Water Market in NSW

To further explore this issue, a methodology is required which can measure the influence of a single attribute (the level of policy flexibility) on the decision of potential water market participants. Choice modelling (CM) was considered an appropriate analytical tool for accomplishing this task.

Choice modelling

CM can be traced back to the seminal work of Louviere and Henscher (1982) and Louviere and Woodworth (1983). However, Carroll and Green (1995) contend that CM itself represents an extension of conjoint analysis, which stems largely from the theoretical contributions of Kruskal (1965), Roskam (1968), Carroll (1973) and Young (1972). Conjoint analysis assumes that consumers evaluate sets of objects or concepts as bundles of attributes. More specifically, the technique seeks to ascribe utility to the various attributes, under the assumption that consumers are able to allocate utility to the various levels of an attribute and then formulate a total utility for the particular product/service/idea.

Products/services/ideas can be real or hypothetical. The aim of the conjoint research is to statistically unbundle the part-worth utilities assigned to various attributes. In this case, varying the attributes of water entitlements, particularly the level of certainty pertaining to property rights, provides a policy relevant context to examine the behaviour of potential buyers and sellers in the water market. This could then be used as the foundation for measuring the transaction costs attendant on policy flexibility.

Any conjoint experiment requires that the product/service/idea be appropriately described, in terms of its relevant attributes and levels, and that respondents are subsequently provided with suitable stimuli (Hair et al. 1998, pp. 387–393). Generally, stimuli are developed using an iterative experimental design process. In this instance, an extensive experimental design process[9] was employed to develop a choice experiment which could be administered to irrigators in the Murrumbidgee and Murray Irrigation Limited districts of southern NSW. Following a pilot experiment, which incorporated three attributes, a simplified choice experiment was selected which included price and property rights as the variables considered to be of greatest interest to potential buyers and sellers of water.

The price attribute was the least difficult to communicate in the choice task. However, specification of this attribute needed to account for the different security of entitlement holders in the survey. The survey specified that the price represented general security entitlements and a high security price was about double that in the choice sets. Identifying appropriate levels for this attribute was problematic. Hair et al. (1998, p. 408) observes that (ideally) the range of attribute levels should be set just outside existing values whilst retaining plausibility. Notwithstanding the information on current prices for permanent water (circa \$450–\$550/ML), evidence from focus groups suggested that such levels were unlikely to invoke changes in the behaviour of many respondents. Accordingly, the repeated selection of the *status quo* from the choice sets would yield little information to quantify the relative importance of stable property rights. Focus groups also provided some anecdotal evidence on the price levels that might potentially encourage significant sales of water entitlements on a permanent basis, with mention of \$1,500/ML and \$2,000/ML by horticulturists and rice growers, respectively. Thus, \$350/ML was taken as the lower bound and \$2,000 as the upper bound, even though

9. A complete description of the experimental design employed in this instance is provided in Crase et. al. (unpublished paper, 2001).

this might be viewed by conservative respondents as implausible.

Specifying and communicating the extent of certainty about property rights and legislative change offered a number of options. Firstly, the extent to which a water entitlement can be changed can be described in proportionate terms. That is, a percentage of entitlement that is 'secure' versus a percentage which can be autonomously changed by government. Secondly, certainty (or uncertainty) can be described in a chronological context where the extent of certainty is encapsulated in the time frame of the right. Thirdly, as suggested by one of the horticultural focus groups, certainty (or uncertainty) can be conceptualised by some combination of a proportional and chronological scale. Notwithstanding the realism of the latter approach, it adds significant complexity to the choice task for the respondent. In effect, this requires the creation of a 'super-attribute' that must then be compared against the other attributes in the choice sets. Moreover, the release of the *White Paper* (DLWC 1999) had focused many irrigators' attention on the time-specific nature of entitlements, with the time frame indicated in the document attracting significant attention. In light of this, and the requirement that the choice task be communicable, a chronological specification was adopted. Again four levels were used to maintain reasonable balance across attributes and minimise potential biases from this source (see, for example, Wittink et al. 1990).

A mail survey employing Dillman's (1978) design method was used to collect choice data. This comprised an original survey with return post and a series of follow-up correspondence. Two weeks after the distribution of the initial survey, a reminder letter was mailed to all respondents. After four weeks had elapsed, a complete survey package was mailed to those who had not yet returned the survey. The survey population comprised shareholders in Murrumbidgee Irrigation (MI) and Murray Irrigation (MIL) districts. The sample frame was stratified on the basis of shareholder type in the case of the former and enterprise type in the case of the latter.

Results

Coding of variables and the base-case scenario

In order to develop models of buyer and seller behaviour, choice attributes and socioeconomic variables were coded for regression. Of particular significance in this instance is the coding applied to describe the *status quo* or base option.

In the current context, respondents were not given details of the *status quo* or base case since the 'choose neither' (no sale; no purchase) option was assumed to have specific transaction implications. One way to approach this issue is to consider the impact on the respondent of selecting either of these options. With regard to the base-case price, we contend that this option can be legitimately coded as a zero. Clearly, if the respondent chooses not to buy, they pay nothing and if the respondent chooses not to sell they receive nothing. By selecting the 'no sale' or 'no purchase' options we further assume that the respondent leaves the property right unaltered from the present circumstances.

The NSW *Water Act* allows for intervention with only minimal notice to licensees. Until recently, administration of the Act had resulted in extractive licences facing renewal every 5 years. However, currently there is a perception amongst irrigators that the administration of their entitlements is changing without warning (see, for example, Brinsley 1998; Brennan and Scoccimarro 1999). A review of the legislative and administrative changes in the NSW water sector reveals that prominent amendments to rights have occurred at approximate 2-yearly intervals throughout the late 1990s. Firstly, in 1995, the Murray–Darling Basin Commission cap was implemented. This was accompanied by six major State reforms in the same year. Secondly, in 1997, the State government announced a raft of additional changes to extend the 1995 amendments. Thirdly, in 1999, the government released the *White Paper* as the foundation of the new *Water Management Bill.* On the basis of this information, a base property right value of 2 years would appear to appropriately describe the *status quo*. Thus, the base-case scenario was defined as a zero price and 2-yearly adjustments to water property rights.

To ensure a conservative estimation of transaction costs, respondents that had previously engaged in the permanent market were omitted from the choice analysis. This adds additional weight to describing the base-case scenario as a genuine 'zero price'.

The coding of all the other attributes and socioeconomic data is summarised in Table 1.

Choice models

In the first instance, basic multinomial logit models were computed. A specialised computer program, *LIMDEP*, designed to analyse models employing limited dependent variables, was used to conduct the analysis. The indirect utility functions specified for basic buy and sell models were as follows:

$$V_1 = C_1 + ß_1 \text{ price} + ß_2 \text{ years}$$
$$V_2 = C_1 + ß_1 \text{ price} + ß_2 \text{ years}$$
$$V_3 = ß_1 \text{ price} + ß_2 \text{ years} \quad (1)$$

Separate buy and sell models were generated. The analysis of buyer and seller data is addressed separately in the following sections.

Buyer models

A t-test of the two alternative specific constants (ASCs) in the basic buy model revealed no significant differences at the 5% level. Accordingly, the ASCs were constrained to be equal across V_1 and V_2. The resulting linear model (buy model 1) was developed along with additional functional forms for the property right variable (YEARS). These included logarithmic (buy model 2) and quadratic transformations (buy model 3). An inverse function (buy model 4) was also tested since it might be justified on conceptual grounds. This functional form results in diminishing marginal values corresponding with increases in the attribute (Whitten and Bennett, unpublished paper, 2001). The PRICE attribute was treated as linear in all cases due to the base-case scenario being assigned a zero price.

Multinomial logit models rest heavily on the assumption of independence applied to irrelevant alternatives (IIA). Moreover, violations of the IIA property should be tested in this type of analysis. One approach to test for such violations, and employed in this instance, is the Hausman and McFadden (1984) test, where comparisons are conducted between a full multinomial model and a model with an alternative removed. If the parameter estimates do not vary significantly across the two models, the IIA assumption holds. The Hausman and McFadden test revealed no significant violations of IIA at the 5% level in any of the buyer models.

Table 1. Definition and coding of variables.

Variable/constant	Definition	Coding
PRICE	Price per ML of permanent water entitlement	0, 350, 500, 1000, 2000
YEARS	Number of years without non-compensated rule changes	2, 5, 15, 30, 99
C_1	Alternative specific constant	Constrained to be equal across V_1 and V_2
AGE	Four-stage Likert scale	18 to 25 = 1 26 to 45 = 2 46 to 55 = 3 55+ = 4
WATER	Total farm water entitlement including general and high-security water	Quantitative
AREA	Total land area of farm	Quantitative
TEMP	History of temporary trade	Dummy variable taking on the value of 1 for respondent having bought or sold temporary water
INSURE	Purchased accident and illness insurance	Dummy variable taking on the value of 1 for respondent ever having purchased relevant insurance

The theoretical validity of the choice models is adjudged on two grounds. Firstly, the overall significance of the models (in this case, chi-square) provides one criterion. Secondly, the extent to which independent variables are significant and meet *a priori* expectations can also be used to assess theoretical validity (Morrison and Bennett 2000, pp. 23–24). In the context of the aforementioned models, all transformations fulfil these criteria. However, given the slightly superior predictive performance of the logarithmic form, buy model 2 was employed as the foundation to further investigate the data.

The process of including socioeconomic variables in choice models differs from that of conventional regression techniques. Since socioeconomic variables do not differ across the choice sets, they cannot be used to predict the option chosen (Blamey et al. 1999, p. 350). There are two main ways of including socioeconomic variables in the analysis. Firstly, they can be interacted with attributes in the choice sets. Secondly, they can be included through interactions with the ASC.

In this instance, a model which allowed for interactions between the ASC and the socioeconomic variables[10] (AGE, WATER, AREA, TEMP and INSURE) was developed using the logarithmic transformation for the YEARS attribute. This is reported in Table 2 as buy model 5. As with the basic buyer models, overall buy model 5 proved to be significant and explained almost 20% of the variation in the data.[11] Trading in the temporary market was not significant, suggesting that previous participation in the temporary market had little influence over the decision to buy water permanently. This can be explained by the near-universal use of temporary trade across the sample. The INSURE variable also proved insignificant. Whilst this might suggest that attitudes to risk play only a small part in determining whether an irrigator buys water permanently, the limitations of employing this variable as a proxy for risk might also account for its insignificance. The AGE variable was significant at the 1% level with older irrigators less inclined to purchase water permanently.

10. In the context of irrigation, most of these variables might be regarded as 'economic' factors.

11. Rho 2 values of between 0.2 and 0.4 are usually regarded as a good fit of the data in choice analysis (see, for example, Henscher and Johnson 1981).

Table 2. Choice modelling buy models with interactions (ASC = alternative specific constant).

	Buy model 5: ASC interactions	**Buy model 6: attribute interactions, significant variables**	**Buy model 7: logarithmic with significant ASC interactions**	**Buy model 8: linear with significant ASC interactions**
C_1	–0.112 (0.286)	–0.998*** (0.184)	–0.228 (0.240)	0.351 (0.220)
PRICE	–0.138E-02*** (0.104E-03)	–.0139E-02*** (0.291E-03)	–0.139E-02*** (0.104E-03)	–0.137E-02*** (0.103E-03)
YEARS				0.109E-01*** (0.119E-02)
LN YEARS	0.401*** (0.429E-01)	0.558*** (0.102)	0.403*** (0.429E-01)	
AGE* ASC	–0.195*** (0.679E-01)		–0.197*** (0.665E-01)	–0.196*** (0.666E-01)
WATER* ASC	–0.117E-04*** (0.391E-04)			
AREA* ASC	0.516E-04** (0.260E-04)		0.241E-04* (0.132E-04)	0.247E-04* (0.133E-04)
TEMP* ASC	0.151 (0.152)			

Note: Standard errors in parentheses; *** = significant at the 1% level; ** = significant at the 5% level; *significant at the 10% level.

Table 2. (cont'd) Choice modelling buy models with interactions (ASC = alternative specific constant).

	Buy model 5: ASC interactions	**Buy model 6: attribute interactions, significant variables**	**Buy model 7: logarithmic with significant ASC interactions**	**Buy model 8: linear with significant ASC interactions**
INSURE* ASC	0.139 (0.120)			
AGE* PRICE		0.459E-05 (0.915E-05)		
AGE* YEARS		–0.178E-02* (0.929E-03)		
AREA* PRICE		–0172E-07 (0.243E-07)		
AREA* YEARS		0.739E-06 (0.609E-06)		
Log-likelihood	–1198.589	–1208.156	–1205.391	–1211.108
Rho 2	0.200	0.194	0.196	0.192
Adjusted rho 2	0.198	0.192	0.194	0.190
Observations	1364	1364	1364	1364
Chi-square	599.836	580.702	586.232	574.798
% correctly predicted	68.793	71.310	69.257	69.306

Note: Standard errors in parentheses; *** = significant at the 1% level; ** = significant at the 5% level; *significant at the 10% level.

The significance and sign of the WATER and AREA variables in this model are more problematic. *A priori* we would expect that irrigators with larger entitlements and those with larger farms are more inclined to purchase water permanently. This expectation derives, in part, from analysis of established trading behaviour in the entire data set. Whilst both variables proved to be significant (WATER at the 1% level and AREA at the 5% level), the signs do not meet *a priori* expectations. The likely collinearity between these variables probably accounts for this as well as the substantial change in log-likelihood.[12] Whilst acknowledging that '...there is no easy way out of the multicollinearity problem' (Kvanli 1992, p. 639), in this instance we address the issue by reducing the interaction of socioeconomic variables to AREA and AGE.

Further insight into the role of these variables can be achieved by conducting interactions with the attributes in the CM. More specifically, AGE and AREA were interacted with the PRICE and YEARS variables to produce buy model 6. The significance of the AGE*YEARS term at the 10% level and its sign suggests that older farmers are less inclined to select an option because of an enhancement of property right than younger respondents. However, the insignificance of the AGE*PRICE term supports the view that age does not substantially influence the relative importance of price in the choice sets. The insignificance of the other attribute interactions suggests that the influence of price and years does not vary separately across farm size.

Even though buy model 6 is significant overall and avoids the collinearity evident in buy model 5, the inclusion of several of the interaction terms does not

12. Kmenta (1971, p. 380) argues that multicollinearity is a question of degree and a phenomenon of the sample. In the present context, collinearity between the AREA and WATER variables might be expected on the grounds that larger irrigation farms usually have larger entitlements. This is supported by our earlier observation that horticulturalists within the study region have, on average, both smaller farms and entitlements than more extensive irrigation enterprises.

appear warranted on statistical grounds at least. Accordingly, buy model 7 was developed to permit estimation of compensating surplus and implicit prices. Buy model 7 combines the logarithmic YEARS transformation with the significant ASC interaction terms, less WATER*ASC to minimise collinearity. The model is significant overall and produces coefficients that are mostly significant at the 1% level and meet with *a priori* expectations. More specifically, higher prices and weaker property rights reduce the probability that a buyer will choose an option. Older irrigators are less inclined to choose a buy option whilst irrigators with larger farms are more inclined to select a buy option.

Seller models

The estimation of seller models followed a similar procedure to that employed for the buyer models. Again, t-tests on the basic models revealed that the ASCs did not vary significantly at the 5% level and were consequently equated. In the first instance, basic models were developed using linear, logarithmic, quadratic and inverse specifications for the YEARS attribute. Each of these models is described as sell models 1–4.

The basic linear sell model (sell model 1) was significant overall and reported a relatively high rho 2 explaining over 31% of the variation in the data. The coefficient of PRICE was significant at the 1% level and had the expected sign. More specifically, increments in price increased the probability that a respondent would select the sell alternative. However, the YEARS variable, which represents the strengthening of property rights, was not significant in this model.

Models employing alternative functional forms for YEARS were generally similar to the linear model. The Hausman and McFadden (1984) test was again employed to test for violations of IIA and none were evident at the 5% level in any of these basic models. Overall model significance, log-likelihood and predictive performance were not significantly altered by the transformation of the YEARS variable. Moreover, the statistical significance of the YEARS attribute was not modified by adopting alternative functional forms.

In the absence of any compelling theoretical or statistical argument urging the use of more complex formulations, the linear model was subsequently employed as the foundation for developing interaction models. These are presented in Table 3.

Table 3. Choice modelling sell models with interactions.

	Sell model 5: ASC interactions	**Sell model 6: attribute interactions, significant variables only**	**Sell model 7: linear with significant ASC interactions only**
C_1	–1.926*** (0.275)	–2.796*** (0.131)	–2.016*** (0.247)
PRICE	0.107E-02*** (0.776E-04)	0.153E-02*** (0.163E-03)	0.107E-02*** (0.774E-04)
YEARS	0.134E-02 (0.140E-02)	0.136E-02 (0.140E-02)	
AGE* ASC	–0.214*** (0.696E-01)		–0.196*** (0.689E-01)
WATER* ASC	–0.200E-03** (0.838E-04)		
AREA* ASC	–0.114E-03 (0.110E-03)		–0.292E-03*** (0.883E-04)
TEMP* ASC	0.203 (0.146)		

Note: Standard errors in parentheses; *** = significant at the 1% level; ** = significant at the 5% level; *significant at the 10% level

Table 3.(cont'd) Choice modelling sell models with interactions.

	Sell model 5: ASC interactions	**Sell model 6: attribute interactions, significant variables only**	**Sell model 7: linear with significant ASC interactions only**
INSURE* ASC	–0.181 (0.122)		
AGE* PRICE		–0.105E-03** (0.442E-04)	
WATER* PRICE		–0.130E-06*** (0.401E-07)	
Log-likelihood	–1068.455	–1075.721	–1073.909
Rho 2	0.320	0.316	0.317
Adjusted rho 2	0.318	0.314	0.315
Skipped	0	0	0
Chi-square	1007.318	992.786	996.410
% correctly predicted	78.001	79.548	79.901

Note: Standard errors in parentheses; *** = significant at the 1% level; ** = significant at the 5% level; *significant at the 10% level

Sell model 5 provided interactions between the ASC and socioeconomic variables. The model is significant overall and produces coefficients for PRICE and AGE that are significant at the 1% level. In addition, the WATER coefficient proved significant at the 5% level. The sign for the significant socioeconomic variables suggests that older respondents are less inclined to choose a sell option as are those with larger water entitlements. In this instance, the Hausman and McFadden (1984) test revealed violations of IIA at the 5% level. In view of these violations, and in an effort to shed more light on the role of interaction variables, sell models 6 and 7 were developed.

Sell model 6 comprises the linear specification for attributes and interactions between PRICE and the significant socioeconomic variables from sell model 5. Interactions with the YEARS attribute were also attempted in alternative models but proved insignificant and are not reported here. Results from sell model 6 suggest that older respondents are less likely to be motivated by price into selecting a sell option. Similarly, irrigators with larger water entitlements are less likely to choose a sell option on the basis of price. These results are not surprising given the significance of the PRICE attribute in sell model 5 (accompanied by the insignificance of the YEARS attribute) and the signs of the coefficients for AGE and WATER in that model. Whilst sell model 6 is significant overall, IIA violations were again evident at the 5% level. Further refinement of the seller models was attempted by combining ASC interactions and attribute interactions. However, this failed to enhance the predictive performance of the models and did little to reduce the level of IIA violations.

Sell model 7 reports ASC interactions with the AGE and AREA variables and constrains the model to a single attribute, PRICE. The inclusion of the AREA variable may be justified on the basis of the statistical significance of WATER in earlier formulations and the formerly described relationship between this variable and AREA. Sell model 7 meets the criteria of theoretical validity. Namely, the model is significant overall and the coefficients are significant and meet *a priori* expectations. The model does not produce significant violations of IIA at the 5% level. In light of the limitations encountered in developing sell models 5–6, policy recommendations are derived by employing sell model 7.[13]

Implicit prices

One of the primary motivations of this research has been to quantify the transaction costs attendant on

13. Blamey et al.(1999, p. 349) recommends that studies providing an important input to decision-making should address the IIA assumption.

the current institutional arrangements in the permanent water market. We have argued that uncertainty surrounding the property rights to water reduces the willingness of buyers and sellers to participate in the market, thereby restricting the capacity of the water market to generate welfare. Here we attempt to quantify this impact by examining the implicit price of more secure property rights from the buyer's and seller's perspective.

Implicit prices are derived by examining the marginal rate of substitution between the PRICE attribute and the other attribute under consideration. In the current research, this has been simplified by the inclusion of only two attributes in the choice sets, YEARS and PRICE. Accordingly, the marginal rate of substitution between these variables defines the buyer's and seller's willingness to pay (WTP) to strengthen the property rights of their water entitlements.

To accomplish the measurement task from the buyer's perspective we employ buy model 7, which embodies a logarithmic transformation of the YEARS attribute and also includes significant interactions with the ASC. The logarithmic transformation complicates the estimation process since implicit prices will vary according to the level of YEARS under scrutiny. The implicit price is derived by comparing the rate of change of the YEARS attribute with the rate of change of the PRICE attribute. This is revealed by differentiating the utility function with respect to each of the attributes. In the case of the linear function this simply reduces to:

$$\text{Implicit price}_{(\text{LINEAR})} = ß_{\text{YEARS}} / ß_{\text{PRICE}} \qquad (2)$$

For the logarithmic form, the implicit price is given by:

$$\text{Implicit price}_{(\text{LN})} = (ß_{\text{YEARS}} / \text{YEARS}) / ß_{\text{PRICE}} \qquad (3)$$

Confidence intervals for implicit price estimates can be calculated using a technique attributed to Krinsky and Robb (1986).[14] Results for the implicit price of a 1-year increment in the property right attribute and related confidence intervals are reported in Table 4. Since the implicit price varies according to the level of YEARS for the logarithmic form, results are reported for each of the attribute levels used in the choice experiment as well as the assumed *status quo* of 2 years.

The implicit prices reported in Table 4 suggest that buyers discount their bids in the permanent water market because of policy flexibility. Using the linear specification (buy model 7) it would appear that buyers discount water bids by almost $8.00/ML for each year of uncertainty. Clearly, interpretation of the implicit prices from the logarithmic form (buy model 8) is more complex and requires further discussion.

The logarithmic transformation applied to YEARS results in implicit prices that decline as the level of policy certainty is increased. Whilst this might be regarded as consistent with diminishing marginal utility, it constitutes markedly different results from the linear form. Interpretation of results is also complicated by determining the 'appropriate level' to be assigned to the YEARS attribute. Whitten and Bennett (unpublished paper, 2001) resolve a similar problem by focusing attention on the midpoint of the attribute levels. Application of this technique and inclusion of the *status quo* would result in greatest attention being paid to the estimated implicit prices when YEARS is equated to 15 (i.e. $18.76/ML).

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14. This procedure employs a large number of random draws from a multivariate normal distribution relating to the estimated parameters. In the current context, 5,000 random draws were simulated using SPSS (Statistical package for the social sciences).

Table 4. Implicit prices for 1-year enhancement of property right.

	Mean implicit price ($/ML)	95% confidence interval ($/ML)	
		Lower	Upper
Linear implicit price	7.93	6.06	10.26
LN implicit price Years = 2	118.12	89.02	152.16
LN implicit price Years = 5	53.18	40.89	68.17
LN implicit price Years = 15	18.76	14.50	24.10
LN implicit price Years = 30	9.57	7.28	12.13
LN implicit price Years = 99	2.93	2.24	3.72

The calculation of the implicit price of improved property rights for sellers is problematic. This difficulty stems from the insignificant nature of the YEARS variable in all the sell models. Sellers do not significantly respond to changes in the property rights attribute alone and would appear to be predominantly motivated by adjustments to the level of PRICE.

The fact that sellers are clearly responsive to PRICE is sufficient to suggest that the permanent water market could become more active with a reduction in policy flexibility. Our analysis of buyer behaviour indicates that buyers are willing to raise their bids when offered greater policy certainty. Coupled with the significance of the PRICE attribute in the seller models, this suggests a more active market for permanent water in NSW.

Estimating transaction costs

Estimates of compensating surplus can be generated directly from choice models. Moreover, we argue that such estimates provide a mechanism for measuring the extent of transaction costs, since they correspond with the amount irrigators are prepared to pay to constrain nonergodic events or hasten the transition to an ergodic state.

In the case of a single before and after option, the measurement of compensating surplus is accomplished by employing the following equation:

$$W = (vi0 - vi1)/\mu^1 \quad (4)$$

In this instance, μ^1 is the marginal utility of income and *vi0* and *vi1* describe utility before and after the change (Blamey et al. 1999, p. 342). Since *vi0* represents the utility associated with the *status quo*, it is calculated by substituting the model coefficients and mean socioeconomic data along with the attribute levels pertaining to the ‘no sale’ or ‘no purchase’ options (i.e. PRICE = 0; YEARS = 2). The value of *vi1* is determined by changing the attribute levels to an alternative scenario (Morrison and Bennett 2000, p. 12).

In keeping with the tenor of the *Water Management Bill*, we assume that the non-attenuation of property rights is increased to 15 years. Accordingly, we endeavour to estimate the compensating surplus that arises by moving from the *status quo* to an altered property right that guarantees no rule changes for 15 years. To gain a perspective of the buyer’s transaction costs, we employ both linear and logarithmic models (buy models 7 and 8, respectively). Of course, all of this is contingent on the firming of property rights being credible in the minds of potential buyers.[15]

The estimates of compensating surplus associated with a strengthening of property rights from 2 to 15 years from a buyer’s perspective are presented in Table 5. Confidence intervals have again been calculated using the procedure developed by Krinsky and Robb (1986).

Varying the functional form assigned to the YEARS attribute gives rise to markedly different estimates of compensating surplus. Notwithstanding these variations, if such estimates are representative of the transaction costs borne by buyers, they are clearly non-trivial.

The problems encountered in estimating implicit prices for the sell models are carried to the estimation of compensating surplus from the seller’s perspective. In the current context, this implies that changing the property right for sellers (presumably reducing this

15. Problems may have arisen from the lack of credibility embedded in the *Water Management Bill* and the role of Clauses 38 and 78 in the proposed legislation.

Table 5. Estimated compensating surplus accruing to buyers by increasing YEARS from 2 to 15.

	Mean ($/ML)	95% confidence interval ($/ML)	
		Lower bound	Upper bound
LN (buy model 7)	586.87	447.60	749.34
Linear (buy model 8)	103.04	78.20	133.01

genre of transaction costs) does not shift the supply function in the permanent water market. However, we have observed that buyers have a defined WTP for enhanced property rights and sellers are strongly motivated by price. Enhanced property rights seem likely to increase the demand for water entitlements by shifting the demand curve to the right.

Policy Implications and Concluding Remarks

Establishing the magnitude of the transaction costs borne by the market as a result of policy flexibility has raised substantial challenges. The choice data assembled to accomplish this task have provided valuable insights into the behaviour of buyers and sellers in the permanent water market in NSW.

Models developed for buyer behaviour reveal that buyers are more inclined to purchase at lower prices or when property rights are more certain. Moreover, potential buyers of water entitlements have a defined and positive WTP for more secure property rights. The range of implicit prices for extending the security of the property right by one year varies markedly with the functional form assigned to the buyer model. Nevertheless, implicit prices ranging from about $8/ML per year (linear model) to $118/ML per year (logarithmic model) suggest that transaction costs from an individual buyer's perspective are likely to be significant. In addition, our estimates of compensating surplus indicate that a move to more stable rules, such as that implied in parts of the *Water Management Bill*, would result in significant reductions in the transaction costs of buyers. Accordingly, we can predict that a firming of property rights will result in an increase in the demand for permanent water.

Enumerating the value of transaction costs from a seller's perspective has proven more problematic. The choice data reveal that sellers are strongly motivated by price and unlikely to chose a sell option on the basis of a change to property rights alone. This supports the notion that sellers of permanent water are more likely to consider selling all of their entitlement rather than a portion thereof. The behaviour of sellers in the choice experiment also suggests that the supply function in the market for permanent water is unlikely to shift in response to changes in the transaction costs that emanate from policy flexibility. Nevertheless, the significance of the PRICE attribute in the sell models points to a more active market in the event that policy flexibility is reduced.

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Legal Issues in Water Resources Planning Regimes—Lessons from Australia

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Abstract

This paper outlines the legal issues in the evolution of the recent water resources planning regimes in Australia. The recent reforms reflect the movement of the debate between development and the environment in Australia, toward concern for the environment. The background to this shift will be explained through the description of the key features of the Council of Australian Governments reform process. Some comments will be made on the legal issues arising out of these changes. The focus will be on present and potential issues, but these of course are inextricably tied up with past administrative frameworks and institutional arrangements. Some of the achievements of the water policy reform mechanisms, especially those relating to the competition issues, are discussed.

THIS paper canvasses some of the many legal issues in the current Australian regimes for water resources management. It may provide some lessons for countries in our region. Australia enjoys the many benefits of a stable and literate population, and it has developed successful models of interstate sharing through the Murray–Darling Basin Commission. However, despite these advantages, there are still examples of situations where water policy reforms have not worked well or quickly. For example, many irrigators still use inefficient irrigation techniques despite education and pricing incentives.

Australia is at the water crossroads in many ways. As a result of obligations under competition policy reforms, Australian governments have recently created eight new sets of laws to attempt to achieve socially, economically and environmentaly positive outcomes in water use. However, many of the regimes are extremely new and so we have not had the benefit of judicial interpretation of the words in the Acts. As the many new situations arise, past events will still influence the judicial interpretation of the words in these new Acts. It is impossible to predict outcomes, but past experience with the law shows that judicial interpretation of State laws may produce results that surprise the policy-makers.

Commonwealth–State Power Relationships: now and in the Future

Two overall points need to be made. At present, the bulk of legislative power over water lies with the States which have water resources and planning powers and deliver the bulk of the everyday living services to Australians, i.e. water, housing approvals and roads. The Commonwealth was not given powers over water at Federation and this has not changed. What has changed is that the Commonwealth is using indirect powers over finances under Section 96 of the Constitution to influence water policy.

This means there are eight legal regimes for management of water in Australia. That has not changed. The Council of Australian Governments (COAG) reforms have extended the ambit of Commonwealth influence in that the reforms described above proscribed issues for the States to address issues such as full cost-recovery pricing. The total amount at stake for the States is $16 billion. The most positive prediction able to be made is that the Commonwealth will extend its influence in this area so we can expect more changes. The Commonwealth is also leading the

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States here in pushing for greater integration of water and land-use planning. The Commonwealth already has some power to pass laws related to water. These include Acts protecting wetlands under treaties such as Ramsar and also Biodiversity. The Commonwealth also has power to regulate the operations of corporations and through this mechanism could impose many obligations on the corporatised service providers (see Table 1). The Commonwealth clearly has power to impose national water-quality guidelines (McKay and Moeller 2000).

Table 1. Status of jurisdictions' progress in implementing competition aspects of urban and rural water reforms in 1999.

Reform	NSW	Vic	Qld	WA	SA	Tas	ACT	NT	MDBC
Cost reform and pricing									
Urban water (1998)									
Full cost recovery	➤	✓	➤	➤	➤	➤	➤	✗	na
Two-part tariff	✓ most large urban	✓	✓ most large local govts	✓ major urban	✓ urban	✗	✓	✓	na
Reduction/elimination of cross-subsidies	➤	➤	✗	✗	➤	✗	➤	✗	na
Remaining subsidies made transparent	➤	➤	✗	✓	✓	✗	✓	➤	na
Positive rate of return	✓	✓	➤ some large local govts	✓	✓	✗	✓	✗	na
Rural water (2001)									
Full cost recovery	➤	➤	➤	➤	✗	➤	na	➤	➤
Consumption-based pricing	➤	➤	➤	➤	➤	➤	na	➤	➤
Reduction/elimination of cross-subsidies	➤	➤	➤	➤	➤	✗	na	➤	na
Remaining subsidies made transparent	➤	✓	➤	✓	✓	✗	na	✓	na
Rate of return	➤	✓	✗	✗	➤	✗	na	➤	➤
Sinking fund	➤	✓	➤	✗	➤	✗	na	➤	na
Investment appraisal	✓	✓	✓	✓	✓ ecol	➤	na	✓ ecol	na

✓ = implemented; ➤ = implementing; ✗ = little or no progress; na = not applicable; MDBC = Murray–Darling Basin Commission; ecol = ecological; reg = regulated; unreg = unregulated; gw = groundwater.

Note: The summary in this table is only a broad indication of progress. It does not purport to provide a complete picture of the details of reform implementation contained in the assessment.

Sources: Productivity Commission 1999; High Level Steering Group on Water 2000.

Table 1. (cont'd) Status of jurisdictions' progress in implementing competition aspects of urban and rural water reforms in 1999.

Reform	NSW	Vic	Qld	WA	SA	Tas	ACT	NT	MDBC
Allocation and trading									
Environmental allocation	reg ✗ other	➤	➤	➤	➤	➤	➤	✗	➤
Water property rights, separate from land	reg/gw ✗ unreg	✓	✗	➤	✓	➤	✓	➤	na
Trading in water entitlements (1998)	➤	✓	✗	➤	✓	➤	✓	✗	➤
Institutional reform									
Separate roles (1998)	✓	✓	➤	✓	✓	➤	➤	➤	➤
Holistic approach to resource management	✓	✓	➤	➤	✓	➤	➤	➤	na
ICM approach to water management	✓	✓	✓	✓	➤	➤	➤	➤	✓
Performance comparisons	➤	✓	➤	➤	➤	➤	✓	➤	na
Community consultation	✓	✓	✓	✓	✓	✓	✓	➤	✓

✓ = implemented; ➤ = implementing; ✗ = little or no progress; na = not applicable; MDBC = Murray–Darling Basin Commission; ecol = ecological; reg = regulated; unreg = unregulated; gw = groundwater.

Note: The summary in this table is only a broad indication of progress. It does not purport to provide a complete picture of the details of reform implementation contained in the assessment.

Sources: Productivity Commission 1999; High Level Steering Group on Water 2000.

History of the Legal Context and the Institutional Arrangements Before the Wave of Reform in 1994

The reforms of the water industry in Australia took place in 1994–95 and are now known as COAG reforms. However, these reforms owe a debt to, and were driven by, earlier reforms such as the 1990 and 1992 Inquiries by the Federal Government Industry Commission. (Industry Commission 1990, 1992, 1997). The first two called for change and pricing reform, based on poor past performance. These 'competition reforms' were set in the background of general competition reforms in Australia in other sectors such as electricity generated by a reform process driven by a report known as the Hilmer report. The COAG reforms directed the State and Territory Governments to draft legislation to fulfil the competition and environmental dual aspects of the reforms in its own jurisdiction. This approach has its merits in quelling State Government resistance, however Australia still has several different approaches and differences in performance measures and targets between the States (WSAA 1999). Issues with this system will be addressed later in the paper.

Rather than public sector provision of water by the public service, we now have Government Business Enterprises in each State and Territory of Australia. These still provide water to urban and rural customers under regulations governed by State law. Increasingly however, the Commonwealth will have a more significant role in the competition structure as these Government Business Entities are fractured into components and corporatised, and in some situations in the rural sector they have been privatised.

The competition reforms of the COAG agenda were set against a background of concern over water resources management—in particular, environmental problems noted by the Senate in 1970s (Senate Select Committee on water pollution) and the view that an important part of the solution to environmental problems lay in policy and institutional change (COAG 1999; High Level Steering Group on Water 2000). The

Agreement was signed by each State and Territory in 1994. The package explicitly links economic, social and environmental objectives. It seeks to improve both the efficiency of water use and the environmental management of the Nation's river systems (COAG 1999).

Hence, the water reforms aimed to promote national sustainable development in the long term by telling the States what to put in their laws. Some had already moved in the desired direction but now all had to. State Water Policies in Australia in the past tended to be very idiosyncratic, e.g. in South Australia (McKay 1994), and insular and introspective.

Requirement to be Economically, Socially and Environmentally Sustainable

As seen above and below the reforms were driven by the triple bottom line accounting requirements to be economic, socially and environmentally sustainable. This was because it would be unsustainable to continue the present water-use trend (Australian Academy of Technological Sciences and Engineering and the Institute of Engineers 1999). So there was a need to adopt adaptive policies based on economic, social and environmental characteristics. These three ideals are difficult to reconcile and some view them as imposing a set of three conflicting ideals on the decision-maker in a system of limited and uncertain information (Benvenisti 1996; Jones et al. 2001). The three ideals appear in all Acts and decision-makers are required to optimise all three. Hence we have seven different attempts at doing this. Some States attempt to make it a duty to try to achieve them all, i.e. Tasmania and New South Wales. All of these attempts are untested as yet and heavily influenced by past practices. The concern here is that within the three areas, different information is available and such information has different levels of reliability. The environmental information is the most difficult to quantify. Social effects can also be perverse. The economic indicators are often the most available. Clearly the water-policy decision-makers in each State have a difficult task ahead of them. The decision-maker is often the Minister and under present Australian Administrative law, most jurisdictions provide a clear power to review such decisions. Hence, the Minister will need to show that his decision was reasonable based on the information available and that efforts were made to collect information.

Disputes will eventually arise and in such cases the rules inherent in other Acts such as the relevant environment court Act will bring a different approach to the resolution which may be seen by some to be at odds with the Water Act. In any event, past judicial decisions in the jurisdiction on like Acts will also be relevant, hence bringing to the fore past practices and former decisions.

The past practices are the social construct in which any law operates. The social construct of water in Australian society has involved the main users—irrigated agriculture (between 72–80%), urban users, industrial users and the environment. To date, there has been little competition between these sectors for water, but that is due to change (as discussed above). So water is the subject of these multiple heterogeneous groups and neither the law nor legal or regulatory institutions are one system, even within each State (see Table 2). The institutions exist within a state of legal pluralism (Griffiths 1986) in which groups may support, complement, ignore or frustrate each other so that the law which is actually effective is a combination of complex and, in practice, unpredictable patterns of competition, interaction, negotiation and isolationism (McKay and Bjornlund 2001).

It is a little too early to be able to assess all impacts of the Australian water reform processes. Detailed studies have not been done but these will evolve. Case studies will be required with regard to the policies, instruments and regulatory framework and community attitudes to these. A long-term general solution to the issue may lie with increasing the information to the community about the issues in water use and in increasing the formality and breadth of the regulation model selected, ensuring the independence and improving the funding and the policing powers of the regulators (see Table 2). Australian data from the Australian Consumer and Competition Council have found the ability of regulators before 1997 to watch the activities of utilities to be patchy (Asher 1999). In 1998, Sydney Water Board essentially wrote its own licence and there was no requirement for public consultation or accountability in licence drafting or amending (McClellan 1998). There have been changes to the regulatory models since then, in part demanded by the community as a reaction to the 1997 Sydney water crisis.

Table 2. Outline of State and Territory urban water authorities' regulatory models up to June 2001.

State/Territory	Number of Acts	Date of latest key Act	Environment	Customer service	Regulatory model
New South Wales	7	2000	Environmental Protection Authority (EPA)	IPART[a]	Corporatisation
Victoria	4	2000	EPA	Price and quality regulator	Commercialisation/ corporatisation/ privatisation
Western Australia	3	2000	Department of Environmental Protection	Pricing control held by Government	Vertical integration
South Australia	6	1997	EPA	Pricing control held by Government	Contracting out
Northern Territory	4		Dept of Lands Planning and Environment	Pricing control held by Government	Franchise
Queensland	8, includes large role for local government	1997	EPA	Qld Competition Authority and Dept of Natural Resources	Franchise model commercialisation
Tasmania	3, local government has a large role	2000	Dept of Environment	Government Price Oversight Commissioner	Commercialisation
Australian Capital Territory	4, included electricity provision	2000		Broad utility regulator outsourced to NSW IPART[a]	Public–private partnership

[a] IPART = Independent Pricing and Regulatory Tribunal

Source: Australian Water Association (AWA) Water Directory 2001 and forum of Chief Executives at the *Water Odyssey* Conference Canberra April 2001. Published in McKay (2000) and McKay and Bjornlund (2001).

Recent Water Resources Audit in Australia

The Water Audit Australia (2001) is an important document, and is the latest in a series of such documents, but much more comprehensive than its earlier counterparts. The Water Audit has assessed the quantity, quality, use allocation (including environmental water provision) and management of surface water and groundwater resources. It aims to promote clear understanding, assess the benefits and costs (economic, environmental and social) of land and water resources, to develop compatible and readily accessible land and water data, and produce groundwater assessments integrated into surface water components, ensuring integration and develop a framework for monitoring.

The Audit has resulted in some first-time agreements between the States, e.g. to breakdown Australia's groundwater resources into manageable units. The report proposes a set of partnership agreements between the Commonwealth and the States to ensure that information is continually collected. At the present time, the data collected provide sufficient information to characterise the surface water quality of approximately 70 of Australia's 246 river basins. These are the most intensively used rivers

The key findings of the Audit are:

- 26% of the 325 surface water management units are either close to being, or already, overused when compared to sustainable flow regime requirements. These account for 55% of the water use in Australia. These basins require the highest priority and additional information and improved methods and tools to assess ecological requirements need to be developed.

- Surface water quality data are limited, with only 28% of the basins able to be assessed for the key variables, turbidity, nutrients or salinity.
- Just under one-third of the 538 groundwater units are either fully allocated or over-allocated when compared to estimated sustainable yield. The management yield needs to be defined.
- Just over half of the surface water and groundwater units are at low to medium levels of development but cannot sustain much more development. Development opportunities need to be explored and water markets are seen as a way of shifting water to higher value uses. Other means to save water are removing open channels, fixing leaks, and water recycling.

Legal Principles in the COAG Water Reform Agenda

The reforms were set against this background of concern over water resources management. The most pressing issues were environmental problems, the need to reform water pricing, and to define water rights in a way that would to encourage future economic development. At a meeting in June 1993, COAG concluded that there were still significant economic and environmental issues, and decided to encourage future reform. An independent committee was set up and the strategic framework generated provided the background to the three agreements set out below.

The National Competition reform process is set out in three inter-governmental agreements (State and Federal) signed in April 1995. These are the:

- Competition Reform Act;
- Competition Principles Agreement; and
- Agreement to implement the National Competition Policy and related reforms.

Legal instruments to adopt the water reform process—*Competition Policy Reform Act 1995*

The reforms of former government-owned enterprises were enacted into law by the States. There was constitutional uncertainty as to whether the *Federal Trade Practices Act 1974* could be extended to cover State government businesses as these generally operated in one State, as seen above. Hence, the legal mechanism used to achieve the extension of the anti-competitive conduct regime of the *Trade Practices Act* was for each State to enact a modified version of Part IV.

The new Part IV of the *Trade Practices Act* prohibits a range of anti-competitive conduct including:

- anti-competitive agreements;
- misuse of market power;
- exclusive dealing;
- resale price maintenance; and
- mergers which have the effect, or likely effect, of substantially lessening competition.

Competition Principles Agreement

The National Competition Reforms have been stated to be a direct response to the need to halt the degradation of water resources and to seek to address economic viability and ecological sustainability of the nation's water supply through the following measures:

- pricing reform based on the principles of consumption-based pricing, full cost recovery (urban by 1998, rural by 2001) and removal of cross subsidies, with remaining subsidies made transparent—encouraging people to use water more wisely by basing their consumption decisions on prices reflecting the actual value of the water they use;
- water allocations or entitlements, including allocations for the environment, coupled with trading in water entitlements—allowing water to flow to those activities bringing maximum benefit to the community (see later discussion of water markets);
- improved water-quality monitoring and catchment management policies and a renewed focus on landcare practices to protect rivers with high environmental value;

- future investment in dams and other water infrastructure being undertaken only after appraisal indicates that it is economically viable and ecologically sustainable—addressing the need for cost-efficient investment with due regard for environmental concerns; and
- structural separation of the roles of service provision from water resources management, standard setting and regulatory enforcement.

Agreement to implement the National Competition Policy and related reforms

This incorporates COAG agendas for electricity, gas, water and road transport industries into the National Competition Policy (NCP) framework. The Agreement also sets out conditions for financial assistance (under section 96 of the Constitution) from the Commonwealth to those States which implement the NCP reforms and the timetable for implementing reform. The total financial incentives between 2000 and 2006 amount to $16 billion. The time frame for reform in the water sector was set at 5 to 7 years from 1994 because of the sheer size and complexity of the package (National Competition Council 1999). The third tranche assessment of the performance of the water industry is due to be completed in mid-2001.

Competition issues in the COAG reforms

The States tackled these issues first and separated the functions of their former public service utilities on the dimensions below. However, the process was not clear-cut. Many iterations of the Acts took place over the period from 1995 to the present and indeed after this third tranche assessment, the Acts may well need to be revised again. Hence, we have a situation of high legal uncertainty at present.

Table 2 shows that multiple Acts are involved in water regulation in many of the States and this in itself is a problem. Many States have only recently enacted the legislation after much community debate on the issue. The number of Acts is a major problem and, whilst the Water Act in each State has been amended, other Acts which are relevant have not been given attention and so may undermine the Water Act. For example, if the Planning Act has not been altered to consider the effects on water quality of new land uses and development then the Catchment Board may have little say. In many cases, that type of situation exists.

Each Water Act in its objectives sets out a number of contradictory goals, i.e. the competition goals and the environmental goals from COAG. These do not need to conflict, but in order to be assured, the management and institutions must provide guidance on how to resolve these conflicting goals. This requires research on the social, economic and ecological effect of different land-use choices. In brief, all the States have incorporated an objects clause which has these five themes:

- to apply ecologically sustainable development;
- to protect and restore water courses;
- to enhance the social and economic benefits to the State;
- to involve the community; and
- to provide for orderly and equitable[1] sharing of water.

Such themes are in themselves contradictory and so the community needs to look to the regulatory approach and institutional frameworks set up in order to be able to make choices when conflicts arise. These aims cannot be met merely by making it compulsory to consider them all. Where the power over these matters rests in another government department, then the achievement of these objectives becomes even more difficult.

Here is a concrete example of legal pluralism as the mechanisms used by each State are developed from long-standing, pre-existing statutes, procedures, institutional arrangements and policies. Many of these are well described in Broughton (1999). These arrangements reflected the different water resources issues and the political and social factors operating in each State.

Environmental issues

The key environmental issues for the third tranche assessment of the COAG reforms have been reported to be 'to determine if the water reforms are generating real environmental benefits' in the realm of provisions for the environment, environmental allocations and water quality. This has been defined by the Cooperative Research Centre for Freshwater Ecology into five criteria and these criteria have been assessed by a multi-disciplinary team (Jones et al. 2001).

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1. South Australia does not require equitable.

In each case, the question was to determine if the legislative, regulatory and institutional frameworks were appropriate to ensure delivery of sustainable outcomes.

The five criteria are:

- the development of ecologically sustainable new schemes or extensions to existing schemes;
- sustainable ecological outcomes in relation to water allocations for the environment;
- delivery of ecologically sustainable outcomes in water trading;
- delivery of effective monitoring programs and indicators of river health; and
- adoption of national water-quality guidelines.

These will be discussed in the next section.

In Table 3, whilst all jurisdictions have met the basic criteria, they have all achieved it in remarkably different ways—again relying on different inherited arrangements. For example, waste-water discharge controls and primary responsibility for water-quality protection are universally located with environment agencies separate from water-allocation agencies. Indeed all jurisdictions have satisfied the criteria although other commentators think otherwise (Nevill 2001). However, the devil is in the detail and clearly there are some better and some worse ways to achieve the criteria, e.g. some that involve Ministerial obligations and some that give a wider discretion to various officials. Indeed, the whole devolution and restructuring of the Australian water industry is built on the notion of separate regulatory structures and judicial enforcement of rules, including review of unfair applications of the laws. Regulatory instruments and judicial enforcement are the key to how successful any regulatory structure will be (Spiller 1996) and how coherently the rules will be applied. At this point in time, there are so many new rules in water, and also political issues arising from other corporatisation issues, that there is much more uncertainty in this arena.

The differences between the jurisdictions makes dialogue between them very difficult (as discussed later). The dialogue is important to build on the nationally compatible data collection instruments to provide for improved information to supplement the Audit.

The Nature of the Environmental Criteria Imposed

Table 3 shows that each jurisdiction has satisfied the basic requirements, however some have provided more comprehensive definitions of the key concepts. It is important to look at the detail, especially relating to two issues—the definitions used, and the breadth and the nature of the obligations. In this section, I will look at these two issues in conjunction with the five points above.

Definition of the key concept of ecological sustainability for new schemes

Some of the States attempt a definition while others do not. *Victoria* is explicit in requiring any work on new schemes or existing schemes to be assessed for ecological sustainability before any changes can be made to a bulk entitlement order. Ecological sustainability is not defined in Section 3 of the Act with all the other definitions, so the ambit of the concept is not defined by the Act but rather by judges, or the definition used in another Act may be used. *New South Wales* also states that the objectives of the Act are to provide and apply the principles of ecologically sustainable development, but these are not defined.

In *Tasmania*, the Minister has powers to exempt a person from the Act, but not if the exemption would be from a requirement not to cause material environmental harm or serious environmental harm. The Minister has power but not the compulsion (section 14) to order a management plan be prepared for an area. If so ordered the plan must include assessments of:

- the quantity of water needed by the ecosystems that depend on a water resource and the times at which, or the period during which, those ecosystems will need that water; and
- the likely detrimental effects arising from the taking or use of water from that resource on the quantity of water available to meet the needs of the ecosystems that depend on the resource.

However, it will be up to a court to define 'ecosystem' as no other definition is imported from another Act and it is not defined in this Act. No doubt a broad interpretation will be taken.

Table 3. State Acts and delivery of selected environmental outcomes, June 2001.

	Sustainability of new schemes			
	Environmental	**Allocations**	**Water trading**	**Monitoring**
NSW	Yes	Yes	Yes	Yes
WA	Yes	Yes	Yes	Yes
SA	Yes	Yes	Yes	Yes
NT	Yes	Yes	Yes	Yes
QLD	Yes	Yes[a]	Yes[b]	Yes
TAS	Yes[c]	Yes	Yes[d]	Yes
ACT	Yes	Yes	Yes	Yes

[a] Environmental flow defined and specified in plans for water allocation.

[b] Test requires that the transfer is compatible with environmental flow objectives.

[c] No State water plan yet though.

[d] Section 97(2)(c) requires that the transfer 'could not reasonably be expected to lead to material environmental harm or serious environmental harm'.

Source: Jones et al. (2001).

In *Queensland*, the relevant Act has a Preliminary to the second chapter, which amounts to an objects clause. This Preliminary sets out that the purpose of the Act is to advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water. The next section defines 'sustainable management', then the term 'efficient use' as used in the definition of 'sustainable management' is also defined. Finally, 'principles of ecologically sustainable development' is defined separately. This definition incorporates the precautionary principle[2] and hence is very modern and robust. It is likely that other cases from other jurisdictions will be persuasive in ensuring this gets the widest possible interpretation in the event of a court decision. Section 12 states that if a function or power is conferred on an entity, that entity must perform the function or exercise the power in a way that advances this Chapter's purpose, i.e. incorporates these three definitions. This is a broad requirement on the entities to advance a broad environmental purpose. In my view, the definitions are all encompassing.

[2] Almost verbatim from the 1992 Inter-governmental Agreement on the Environment.

Sustainable management is management that:

- allows for the allocation and use of water for the physical, economic and social wellbeing of the people of Queensland and Australia within limits that can be sustained indefinitely;
- protects the biological diversity and health of natural ecosystems; and
- contributes to the following

  1. improving the planning confidence of water users now and in the future regarding the availability and security of water entitlements,
  2. contributing to the economic development of Queensland in accordance with the principles of ecologically sustainable development,
  3. maintaining or improving the quality of naturally-occurring water and other resources,
  4. protecting water, water courses, lakes, springs, aquifers, natural ecosystems and other resources from degradation and, if practicable, reversing degradation that has occurred,
  5. protecting Aboriginal interests,
  6. providing for the fair, orderly and efficient allocation of water to meet community needs,
  7. increasing community understanding of the need to use and manage water in a sustainable and cost-efficient way,
  8. encouraging the community to take an active part in planning the allocation and management of water, and

9. integrating administration of this Act with other natural resources Acts.

'Principles of ecologically sustainable development' is defined as:

- decision-making processes should effectively integrate both the long-term and short-term economic, environmental, social and equitable considerations;
- if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;
- the present generation should ensure the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;
- the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making;
- recognition of the need to develop a strong, growing and diversified economy that can enhance the capacity for environmental protection; and
- decisions and actions should provide for broad community involvement on issues affecting them.

Section 35 requires that the Minister must plan for the allocation and sustainable management of water to meet Queensland's future water requirements, including for example, the protection of natural ecosystems and security of supply to water users. The Chief Executive Officer must provide information for planning purposes. The Minister may then prepare a water plan under section 38 for any part of Queensland.

In *Western Australia*, sustainable management is the management of the use, development and protection of the State's water resources so as to allow Western Australians to provide for their social, physical, economic and cultural wellbeing while:

- ensuring that water resources are able to meet the reasonably foreseeable needs of future generations;
- safeguarding the life-support capacity of water resources; and
- avoiding, remedying or mitigating significant adverse effects of activities on the environment.

All persons administering this Act must have regard to these objectives. New schemes and extensions to old ones thus need to meet the sustainability criteria. These criteria are considered to amount to a 'duty of care' and would apply to all users including the Commission, landholders, including holders of Native title.

The duty to implement ecological sustainable water allocations for the environment

In Queensland, the environment is recognised as a legitimate user of water, as shown above in the definition of sustainable management. Environmental flow objectives are specified in the Act to be relevant criteria in creating plans in section 46(3) if the plans provide a framework for water allocation. 'Environmental flow objective' is defined in the dictionary to the Act to mean, for a water resource plan, a flow objective for the protection of the health of natural ecosystems for the achievement of ecological outcomes.

In New South Wales, the monitoring program describes as offences breaches of the Act which amount to breaches of the plans and breaches of the licensing provisions. If a management plan is created, the content of it is highly specified in section 34. It must have:

(a) a vision statement;
(b) objective consistent with the vision statement;
(c) strategies for reaching those objectives; and
(d) performance indicators to measure the success of those strategies.

(c) and (d) would require specification of monitoring methods.

Such onerous requirements may make it hard for the Government to find persons willing to serve to draft such plans and hence no objectives, which are truly sustainable, can be achieved or monitored.

Ecologically sustainable development and water trading

The water trading provisions in Queensland are found in sections 70 onward. A person proposing to use water for irrigation must have a water and land management plan and such plans must conform to guidelines if these are set out by the Minister (sections 72 and 73). There are some exemptions to the requirement to have a plan. Once a plan exists, then resource operations plans and operations licences will be issued and old water licences will be converted into water allocations (Section 94). Then in section 94(b), dealings with water allocations can be registered.

Section 98 gives power for the Minister to set up a plan which may limit the ability to trade water between different locations in or outside Queensland or for different purposes. In any conflict, the plan prevails over any licence (section 125). The registration details required for water allocation are comprehensive, requiring details of the purpose for which the water may be taken. At all times, any transfer is subject to the conditions set out in section 134. The registration details include that the transfer is compatible with environmental flow objectives, and water allocation security objectives, and is in the public interest, and the transfer will not significantly affect water entitlement holders, resource operations licence holders or natural ecosystems in an adverse way. This reinforces the Chapter 2 provisions in assessment criteria 1 above. The same rules apply for the lease of a water allocation.

Legislative, regulatory and institutional frameworks to ensure the delivery of effective monitoring programs for river health

In Queensland, the Minister is required to collect data in order to be able to set the plans in place to meet the multiple objectives (section 47 of the Act). One would expect that this requirement would eventually lead to an effective scheme of information gathering. Such a bold and clear obligation would leave the Minister open to a review of his decisions if he had not collected enough adequate river-flow data. Indeed, the Minister must give public notice of his intention to draft a plan in an information report under section 39. Part of this report must include the

> proposed arrangements for technical assessment using best scientific information available and relevant to the preparation of the plan.

The contents of the final plan are described in section 46 and these require the Minister to

> state the water and natural ecosystem monitoring requirements to assist in assessing the effectiveness of the proposed management strategies.

In the Australian Capital Territory (ACT), section 4 of the Act imposes powers on the Authority, one of which is to keep the state and condition of the water resources under review, and under section 99(d) to compile and maintain up-to-date information relating to the water resources of the Territory.

These are a must-type obligation. This is further reinforced in section 17 where the Authority is again obliged to 'ensure as far as possible, that a continuous program for the assessment of water resources of the ACT is carried out'. The Authority is then given a further series of powers and may install equipment on private land as in the Northern Territory (identical provision). Of course, here the 'as far as possible' tends to reduce the urgency of the obligation.

In South Australia, section 6 of the objects states clearly that there is an obligation to keep the state and condition of water resources of the State under review. There is no limitation on these words so the Minister must do it.

Section 92 also specifies the content of plans for prescribed resources and this must:

- address the quality and the quality of the water comprising the water resources of the Catchment Board;
- assess the health of the ecosystems that depend on that water; and
- assess the need for water of those ecosystems.

A plan done for the Onkaparinga Catchment Board does not have a complete assessment of the water needs of aquatic animals such as fish and invertebrates nor flora but it does include terrestrial animals.

New South Wales has a system for identifying stressed rivers.

Adoption of national water quality guidelines

In the ACT, Section 14(1)(g) imposes the function on the Authority to implement national water resource measures made under national scheme laws or intergovernmental agreements relating to water resources management. This is the ideal clause to insert and I am sure the Commonwealth would see this as a model for the other States. This would oblige the national water quality guidelines be followed. No other State is so specific—many have prepared plans, but most often quality of water is referred to but not specified. If the matter were litigated, a court would take judicial notice of the national guidelines.

In Western Australia, salinity is the major issue and the plan process above will be involved in making the hard choices in deciding the local rules for use. The State Water Quality Management Strategy has been through Cabinet for approval as implementation of the National Water Quality Management Strategy. This was submitted in February 2001 and had an 8-week consultation period.

The Western Australian Government can foresee resourcing problems for Western Australian resource management agencies.

In many States, the Health Department is responsible for the administration of these guidelines.

Review of the COAG Principles up to 2001 and Future Issues

All regulatory schemes need to be considered as to whether the nature of the obligation imposed is clear enough to be enforceable. This requires clarity between Acts as well as within any one Act. The next step is to see if the legislators devote enough funds to properly enforce the Act. In addition to these general questions, there are specific issues related to the water reform laws in each State.

Each jurisdiction has implemented the reform package in a different way and with varying rates of progress. This reflects differences in starting points, the nature of the water resources, and also the underlying difficulties of a reform process that involves extensive social and institutional change as well as potential changes to the way some river systems operate (COAG 1999). It has been reported that momentum has been lost on environmental issues in some jurisdictions (COAG 1999). Some commentators argue that the reforms have generated environmental damage in themselves as 'newly privatised bodies seek to expand their market share by reducing prices'. The example cited is the consumption of more coal to generate electricity—this has increased as it is cheaper but not environmentally friendly (Walker and Walker 2000).

Pricing

The requirement is to achieve full cost recovery in the rural and urban sector. Priority needs to be given to identifying and including the costs of resource management and environmental degradation into pricing. (COAG 1999, *Water allocations*).

Work also needs to be done on:

- improved security of rights to water;
- the issue of allocating water to the environment with priority given to stressed rivers. This will be progressed by improved scientific information and effective processes for community involvement; and
- water trading to effectively incorporate consideration of the social, physical and ecological constraints into water-trading policies.

Communication packages

These are needed to ensure community acceptance and more work will be done in this area. This is a general trend in many areas of water reform (Beckwith and Syme 1990; McKay and Moeller 2000).

Coordination of the reform package

The jurisdictions were responsible for implementation and proceeded alone. There was recognition that some issues were common and so in 1998, the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) established a High Level Steering Group on Water. This Group has initiated and recently reported on many issues. The High Level Group is to work to assist the jurisdictions in the priority areas to help realise the full economic and environmental gains of the reforms.

Other major outstanding legal issues are:

- compensation for reducing pre-existing water allocations;
- compensation for using the power in each Act to reduce water allocations;
- assessment of compliance with licence conditions;
- composition of the community groups involved in any local water plans;
- extra-territorial nature of the Acts to include interstate catchments and water allocation issues upstream;
- consideration of whether water is considered to be a good under the *Trade Practices Act*; and
- regulation of potential monopolistic behaviour of water-market participants.

Interstate Water-sharing Issues and the Legal Basis for Existing Cooperative Schemes and Future Issues

Australia has some excellent models of interstate cooperation and these have been implemented with little litigation. The Murray–Darling Basin Agreement spans four States and is a long-standing, well-recognised example of interstate water sharing. In addition to this, various agreements exist between States on rivers not in the Basin, such as the Border Ranges (two States) and the new Lake Eyre Agreement (three States). These agreements are clear in scope, imposed by law but built on community agreement, and apply to identified common pool resources which are excludable and rival. The agreements also were based on the achievement of criteria but left it to the States to evolve the mechanism to do that.

The approach adopted in these old agreements in Australia is one similar to the United Nations Convention on the non-navigable uses of international water courses. States were invited to comment and the Convention was adopted in 1997. It has still not been ratified, as it has not been signed by enough member countries. It is not clear whether this will enter into force, however it still provides clear guidance to States engaged in negotiating on interstate water resources. The treaty has been cited in the international court of justice in a recent case involving Hungary and Slovakia[3] on the Danube River. The judge said:

> Community of interest in a navigable river become the basis of a common legal right, the essential features of which are the perfect equality of all riparian States in the use of the whole course of the river and the exclusion of any preferential privilege of any riparian State in relation to the others.

So in many ways Australia has adopted this response for the big interstate issues but is now moving to look at the more vexing intrastate issues. Each State now needs to achieve the three sustainability objectives (economic, environmental and social) internally with considerable weight toward the environment. It is not clear how much the community shares the ideals and embraces the changes nor the mechanisms. For example, it is still interesting to note that only Queensland mentions that the purpose of its Water Act is to promote sustainable water management to assist the people of Queensland and Australia. Queensland also provides in section 98 a specific requirement to consult other States. However, the current Minister for Water Resources in Queensland has decided not to consult with New South Wales on the setting of the Queensland cap on water use under the Murray–Darling Basin Agreement.

Australia has a hybrid set of legal rules for water which have co-existed. Some rules like the ones regarding interstate water sharing have been implemented well, in part because the community could see the local problem, and because the legal enforcement mechanisms were well funded. Australia is facing a more difficult problem in its intrastate water management and regulation of diffuse pollution from agriculture. In the urban sector, Australia is facing issues relating to separation of functions of pricing and maintenance. It is early days to evaluate the mechanisms selected through COAG.

Conclusions

This paper has described the recent legal regimes for water management in Australia. In many ways we are in a different situation to other countries, having managed interstate issues through cooperative agreements based on clear rules. Australia is now looking at the more difficult issues of promoting the COAG reforms that deal with the difficult issues of corporate reform and full cost-recovery pricing, and diffuse pollution management. Australia has many luxuries including a stable political environment, and a literate population. However, these reforms are challenging even in this environment. The requirement to focus on the environment in conjunction with the economic and social sectors is a major challenge. There will be many problems in implementation and enforcement that arise from the nature of the drafting.

Australia is now poised to provide further case studies of this difficult process. In law, it is important to learn from existing legal systems, no matter their juridicial basis, and to reflect on the social setting of the laws and administrative procedures. With time, Australia will generate a set of case studies on the implementation of current reforms, and laws will evolve through amendments that will eventually lead to a set of policies that truly cater for sustainable water development.

3. Gabcikovo-Nagymaros Judgment of 25 Sept 1997.

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Some Principles for Development and Implementation of Water-allocation Schemes

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Abstract

In the context of increasing pressure on water, from both increased demand and deteriorating quality, the allocation of water is becoming more important throughout the region. Several factors contribute to the ability of governments, organisations and community groups to allocate water. Important elements are (a) law and custom, (b) institutions and organisation, (c) policies and rules, (d) procedures for negotiation, agreement and participation, and (e) resources, both human and technical.

In addition, water needs to be allocated at different levels: from the macro level (across and between river basins) to the micro level (e.g. distribution of water between neighbouring irrigation units) and other levels between. The types of activity and methods for participation may differ greatly, depending on the scale and nature of water allocation involved.

Where countries or jurisdictions are facing the question how to manage increasing conflict over water and obtain optimum benefits, they may conclude that the mechanisms of the past and present need improvement. Ideally, their legal, institutional, policy and resource capacities would be developed together at the appropriate scale, but in reality it can be a heavy task and it may be difficult to develop all of the important elements in harmony.

Therefore, national and sub-national jurisdictions need to consider the progressive and targeted implementation of improved water allocation and management capability, while keeping the possible long-term future in mind. Judgements must be made about where to focus the effort and at what scale to develop allocation mechanisms.

This paper discusses issues for the development of water allocation schemes.

THE allocation of water resources to users of all types is a critical element in the field of activity known as 'water management'. Since history began, water has been allocated in various ways, under numerous legal and institutional arrangements and according to countless traditional and customary rules or systems, which have usually been closely identified with the social structure of the society using the water. The 20th century has seen the promotion of formal legal and administrative systems to manage water in a comprehensive manner and for sustainability objectives.

A simple definition of water allocation is: *the sharing of water among users*. A useful working definition could be: *Water allocation is the combination of actions which enable water users and water uses to take or to receive water for beneficial purposes according to a recognised system of rights and priorities*.

For the purposes of this discussion, water allocation is taken to include all forms of water sharing: that is, the activities and methods which are used by human society to share or distribute water. Water sharing enables water to be allocated and used according to a recognised system of rights and priorities. Recognition of water sharing and the rules which govern access to water may be formal, as governed by legislation, or may be informal and unwritten, as when a group of water users or a community group adopt understood rules for local water distribution. Formal and informal systems of rules may coexist and in very many irrigation schemes do coexist.

The reasons for increasing pressure on water resources are well known. They include the expansion of demand for water and the reduction in availability of water, both its quantity and quality. Water availabil-

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ity is also affected by variability—this is becoming more extreme in some cases as a result of human activities (for instance, alteration of catchment characteristics by reduction of vegetation cover).

The end results are two-fold: firstly, an increase in instances of conflict between water users who abstract water from the same water sources and, secondly, the degradation of water sources. These impacts are compelling governments to pay more attention to management of water resources in a comprehensive sense. A central element of such management is the allocation of the water for use.

Characteristics of water allocation systems being promoted in the 21st century are:

- *their comprehensive nature*—they need to incorporate and coordinate the way in which water is taken by all types of water users, as these users interact with the water source and cause impacts to be felt by others;
- *a legal basis which provides guarantees* to water users that their entitlement to water will be maintained and not eroded—this is normally expressed in a form of water right, which can be guaranteed in various ways, including the judiciary alone (so-called property rights), government policy and legislation or a combination of public and private action;
- *institutional arrangements specifically dedicated* to implementing water allocation schemes, based as closely as possible on the hydrologic unit rather than other jurisdictional units such as regional, local and municipal governments; and
- *explicit development of government policy* on water management and water policy.

These characteristics differ from the methods of the past which have been to a greater extent piecemeal and have included informal mechanisms. This may not appear the case in 'common law' countries, where water rights have developed over long periods through legal precedent, but even in such countries the 20th century saw a significant development of special institutions and laws to coordinate water rights and manage water activities in an active sense (Scott and Coustalin 1995). The present global emphasis on ecological sustainability, being promoted through international organisations, also pushes water allocation in the direction of comprehensive and formal rules.

Where countries or jurisdictions are facing the question how to manage increasing conflict over water and obtain optimum benefits, they may conclude that the mechanisms of the past and present need improvement. Ideally, their legal, institutional, policy and resource capacities can be developed together at the appropriate scale, but in reality it can be a heavy task and it may be difficult to develop all of the important elements in harmony.

A series of water allocation principles was developed by the author for the United Nations Economic Commission for Asia and the Pacific (ESCAP), and subsequently reviewed by a workshop of water-sector participants representing regional countries. The principles are stated in the ESCAP report which resulted from the regional workshop (ESCAP 2000).

This paper gives some background to the issues which the principles are intended to address. The following discussion identifies the major elements affecting the development and improvement of water allocation mechanisms. In ideal circumstances, a balance would be maintained among the development of suitable government policy, institutions, legislation and resources, so that realistic implementations attempts are made. Some particular issues for irrigation and water markets are noted, given that irrigation is the major water user globally and water markets are receiving considerable attention as a solution for water conflicts and in relation to water rights security.

Elements of Water Allocation

At the simplest level, water allocation is the sharing of water between water users, by whatever means and mechanisms. The key to effective sharing for human use is certainty—therefore, the idea of rules which are complied with is important. Water is a 'common pool' resource. Except where water is privately owned with significant tracts of land, water used by an individual it is always taken from a common pool from which others also derive benefits. Therefore, the rules for taking water must take into account whether others are impacted by the taking of the water, and whether that impact is agreed to and considered reasonable, and what is to be done if the water taken exceeds the agreed bounds or becomes unreasonable.

However, there are very different scales on which water may be taken and at which allocation-related mechanisms may apply. The last half-century has seen the construction of large, water-based schemes for irrigation, power generation, industry and water supply/sanitation. When these were installed, the allocation of water to them and to others affected may or may not have been considered explicitly. Even if the right to water was considered, a mechanism may not have been introduced to ensure that the water allocated was taken in such a way that the rights of others were protected. Where formal water allocation mechanisms have not existed, there has been no simple way to ensure that the sources from which water is taken are protected.

We can classify the supporting elements needed to allocate water in the following categories:

(a) policies and plans;

(b) institutions and organisations;

(c) legislation and associated rules;

(d) procedures for participation, negotiation, agreement and resolution of conflict; and

(e) resources for implementation in two areas—

(i) human capacity and

(ii) technical facility.

These groupings of activity relate to modern water allocation schemes which seek to enable water to be managed comprehensively, but they are also present to some degree in all water use and allocation situations, as explained below.

Policies and plans

Policies and plans refer to written or articulated documents that set out how water will be allocated. Governments in developing countries frequently have formal policies for the development of economic sectors, such as irrigation, industry and power generation, and for health, sanitation, regional development and other functions which affect water resources. These policies have a bearing on water allocation at a macro level, particularly where governments aim to ensure that water is available for such projects. In addition, they may develop strategic plans that identify how development is to occur, with implications for water demand.

International organisations are promoting the development of water management policy at a national level (Arriens et al. 1996). Such policies are expected to refer to the use of water and its allocation. The major advantages of an effective water allocation policy are that:

(a) government priorities and the implications for water resources are considered more actively;

(b) water users and people who benefit from water can more easily see the government's intentions; and

(c) implementing agencies have a better guide to priorities and decision-making.

It may seem artificial to separate policy rules from legislation, as legislation involves enforceable rules. However, it is useful to look at the policy setting for water allocation before developing legislation, since the law should be the means for implementing policy. One way of facilitating the introduction of new and comprehensive water legislation is to negotiate the main policy elements beforehand.

Planning, as a means for setting out a series of allocation rules, is being adopted more commonly. Reasons are:

(i) a plan can be used to define the rules which apply in a defined area;

(ii) planning can be used to deal with numerous small water uses which have a significant cumulative effect (though this remains a difficult problem to handle); and

(iii) plans are used as a means to consult with stakeholders, through the plan-making process.

Water management plans which have significant water allocation elements have been developed in Europe (e.g. Spain), the United States and Australia and are being considered more widely. Water allocation plans that have statutory backing in various forms are becoming more common.

Institutions and organisations

The range of institutions involved in water allocation can be considerable. Several types of organisation are involved, but they may be classified into those that determine water rights or entitlements and those that supply water. It is not uncommon to find that the first area of responsibility is not well defined in organisational terms and is undertaken *de facto*, by constructing water-using schemes. An example is the ministry or department responsible for irrigation or power generation which 'allocates' water by constructing dams or diversion works.

Thus, at a national level, water allocation may not be a formal function but in practice may be undertaken by a number of agencies or ministries, each responsible for its own sector, for example, irrigation ministries or departments that allocate water to irrigation schemes by constructing them, and an energy ministry, department or corporation which similarly allocates water to itself by installing power generation schemes that use water. Without an institutional mechanism for harmonising such uses, they will eventually conflict and without a formal water allocation function, there may be little to prevent a new scheme from being constructed upstream and depriving an existing downstream scheme of water. Deprivation of water may not occur at the time of construction but after a period of years, when the upstream scheme increases its water demand.

On the other hand, governments are being encouraged to assign the water allocation role to a single agency, in order to create a consistent and comprehensive water management regime. Irrigation agencies have tended to assume water allocation functions over time, partly because they collect water data and investigate water availability on a broader scale than most other agencies. A different problem arises where the agency in question also owns and constructs schemes that use water. It has a conflict of interest which is likely to (a) bias its allocation decisions towards its own schemes and (b) limit the interest of other sectors in real cooperation.

At the level of the water-using project, schemes which exert significant control over the flow in a river or extract significant volumes from groundwater also control much of the allocation of water from that source. For instance, a headwork dam controls flow downstream and limits or makes available water to anyone in the affected reach of the river. If the scheme's operational rules are changed for any reason, the water availability to downstream water users could be affected, whether those users are supplied by the dam or not.

For irrigation, another level of institutional activity occurs within the scheme. The way in which water is distributed throughout an irrigation scheme affects who receives water and the timing. The operational rules are determined by the operator, which may be a government agency or a cooperative organisation. Modern and recently-constructed irrigation schemes usually perform to an engineering design which is managed by operators who decide on technical grounds how to distribute water most efficiently through the system. If the operator alters any important operational rule, the water available to some users may be affected—in reality affecting the allocation of water within the scheme. In all cases, operators have to make ongoing technical decisions about the operation of the scheme which have allocation implications. Such decision-making at the technical level is very different from allocation decisions made according to formal legal determinations, but is equally important to the water user.

Legislation and rules

The current trend is to promote comprehensive water rights legislation to:

(i) formalise existing water-use activities;

(ii) allow for new uses to be incorporated on a consistent basis with existing uses; and

(iii) enable water to be set aside or managed for non-consumptive reasons, including the environment and other purposes such as flood mitigation, fisheries, navigation and recreation.

Without a legislative basis, no firm water right can be relied on. In many cases, water received by water users results from administrative decisions by arms of government. This may satisfy situations where water users have a direct political connection with the government. However, as the trend to self-management in irrigation continues, and as the private sector takes a greater role in the water sector, firmer legal definitions of water rights and guarantees of their security are being sought.

Another trend is for specialised legal mechanisms to resolve conflict. Water legislation is seen as a way to define water rights such that conflicting uses are bounded and defined. Legislation which establishes a system of water rights is necessarily complex and must include a number of elements at a minimum:

- the creation of a form of statutory instrument which creates the right and the rules for issuing or formalising those rights;
- procedures for obtaining water rights, renewing them if necessary, and modifying them;
- legal procedures for challenging the issue of water rights, where such rights are seen to infringe on the rights or interests of others;
- compliance powers to enable an authority to take action where water rights are exceeded (i.e. where water is taken illegally);

- authorisation of the institutional framework for managing the system of rights (which may include registers, data collection and associated powers); and
- legally binding policy criteria (such as provision for the environment) and priorities to be assigned to different water uses.

Nevertheless, other forms of longstanding water-user practice, social expectation and tradition may perform the same function as water legislation in respect of water allocation. The difficulty is that such practices and traditional rules usually apply in a fragmentary way to water use, whether to a limited location, to certain types of water use and not others, or within the bounds of local communities. They do not apply to recently-constructed projects, where administrative rules and technical guidelines may take the place of legislation.

There are examples in the Asian region of comprehensive water law being adopted before the capacity for implementation has been developed, for instance, in Vietnam (WRCS 2000).

Participation and negotiation

Procedures for participation and negotiation could be viewed as part of the institutional set-up, but it is also necessary to develop ways of obtaining acceptance and agreement to water allocation rules. Public agencies cannot successfully enforce water allocation rules unless they are seen as reasonable and fair by water users as a whole, and also by other social groups with an interest in water. The number and variety of water users will defeat any attempt to impose conditions that are not accepted as reasonable. Similarly, conflicts could be resolved purely by judicial determination, but that requires a robust and sophisticated legal system for water allocation, which simply does not exist in most countries. Therefore, the field of negotiation and conflict resolution needs special attention in relation to water entitlements.

Coordination is also a major issue for water allocation. Coordination mechanisms may be appropriate at the river-basin scale (possibly through a river-basin organisation), at a sub-basin scale (or across a groundwater extraction area), or between regional and local governments, between water using sectors, between large water projects or in other configurations. Coordination is basically required in order to link together various human organisations which participate in the hydrologic unit or sub-unit.

Coordination can be used for a number of purposes which include obtaining consistency of approach between government agencies, obtaining the input of all sectors to policy development, and inclusion of water-user participants in agreed plans, policies and measures.

Resources for implementation

The foregoing elements cannot be implemented without people and other resources. Skills are required for water allocation in a number of fields. These include technical capabilities such as the ability to assess the availability of surface water and groundwater, model and predict its behaviour and identify the impact of water demand on the resources. In addition, scientific expertise in water quality and biology are required to determine the impact of activities on water and on the environment. Equally important are capabilities in planning, consultation and dispute resolution.

It should not be forgotten that financial resources are required to introduce and maintain special institutions and mechanisms for water allocation. Generally speaking, this is not an area traditionally funded by governments in developing countries. Therefore, policies and sources of funding have to be identified and agreed. This issue may be as controversial as any aspect of water allocation. In fact, a common reaction to proposals to better define water rights or to obtain information about water use is the fear that the purpose is to raise money from water users.

Other Issues for Water Allocation

Formal and informal mechanisms

The elements listed in the previous section exist in some form wherever water is being used, whether or not a formal and comprehensive water allocation system has been developed. To illustrate, in the case where customary water use involves domestic water for a village, there will be socially understood policies governing who has access to the sources in normal times and when water is scarce. This would apply to wells if they served more than one family or household, as well as to any constructed surface water supply system in the form of channels, bamboo pipes or whatever. To the extent that any infrastructure needs to be maintained, there will be a concept of organisation and responsibility for it. The policies and guidelines have the force of law in the sense that the community in question will enforce them. The procedures for negotiation and conflict resolution may be indistinguishable from the general social government of the village, but they will be applicable to water use. And finally, knowledge and effort will be applied to the water system, at the appropriate level of technology.

Within traditional irrigation schemes, all these elements are likely to be more highly developed, with a combination of formal and informal guidelines and rules governing the timing and flow of water in supply channels and from one field to another. These rules are likely to be closely tied to responsibility for contributing to the maintenance of the irrigation scheme.

An important point, therefore, is that the development of a new water allocation regime, or the enhancement of water allocation schemes, is not undertaken on a 'blank page', but should be seen as building on what already exists. Although new elements may be introduced, they must be consistent with or acknowledge as far as possible the pre-existing water allocation mechanisms.

Continuing change

No water allocation system is static. All water allocation systems must be managed on a continuing basis. This is for several reasons. Firstly, the availability of water resources may change due to numerous factors (climate, urban/industrial development, change in quality) or previous technical estimates may be later shown to be wrong and changes need to be made to expectations of water allocation. Secondly, the nature of water use and development is constantly changing. Apart from expansion of development and water use, the pattern of use may change. Such changes are common in irrigation, where water use is seasonal. Changes in crop type or watering practice by one group may affect how water is available to them and to others. Thirdly, the condition of infrastructure may change, leading to higher or lower water distribution efficiency. Changes of this nature may affect water inside and outside the scheme (for instance by reducing drainage volumes that supply other users).

The implication is that an ongoing water allocation function exists whether or not it is recognised. It may be performed through the operation of an irrigation scheme, or it may be conducted through a system of planning at the river-basin level, where, for instance, reassessment of water availability results in the renegotiation of certain conditions applying to the taking of water. In between are many decisions regarding the rules for taking water.

The 'de facto' effect

The 'de facto' allocation of water was mentioned earlier. It is common to find examples of water-based schemes which have significant impacts on rivers, but where the water allocation question has not been adequately dealt with. The World Commission on Dams (WCD 2000) noted that various rights, including water rights, affected by large dams were not well addressed. In that report, issues which could be classed as related to water allocation in the broad sense included downstream aquatic ecosystems and biodiversity, fisheries, reliance of indigenous people on river-affected habitat and cultural heritage.

The installation of schemes has commonly included the assumed or, less commonly, an explicit approval of the government that the required water could be taken by them. However, such approvals rarely quantify the water to be taken. Such decisions would be based on a technical assessment that the water was available at the relevant point. The same has occurred in developed countries. For instance, the largest dam for the water supply to Sydney, Australia, was constructed in the 1950s (Warragamba Dam) and no defined water entitlement was assigned to it, nor any obligation on the operator to release water downstream for the environment. Although some flow was to be maintained to provide for riparian river pumpers, there was no administrative mechanism for ensuring that such flow would be maintained until the issue of a water licence in the year 2001.

In cases where water is to be provided for downstream purposes, there may be no way to enforce it. For example, the environmental impact assessment for Babagon Dam, the water supply dam for Kota Kinabalu, Sabah, Malaysia—completed around 1994/95—proposed that a passing flow be maintained. However, no agency of government was responsible for ensuring that the flow would be passed, nor was there an administrative mechanism for imposing such an obligation on the dam operator (WRCS 1995).

In many countries, large-scale water developments are being introduced in situations where water has traditionally been taken and used in smaller quantities and on a smaller scale. Whereas large urban water supply schemes generally reflect communities which have developed in a new form, rural water schemes, notably irrigation supply schemes, are constructed across areas where previously there may have been other forms of water use. De facto allocation of water is common in such circumstances.

Issues of scale or 'level'

Although water allocation or water sharing can be considered as a whole, in reality it is undertaken at different levels or scales, and the nature of participation and activity at these different scales is also quite distinct.

Water allocation at the macro or large scale is undertaken firstly at the level of the river basin or between river basins, and secondly between nation states. At these scales, governments must be represented directly or must create governmental institutions or arrangements directly. For instance, there would be few, if any, river basins of an appreciable size which are managed by a private sector scheme. River-basin management is a subject in its own right, receiving increasing attention since the early 1990s. Water allocation at the level of the river basin generally involves the sharing of water between sub-sectors of the water sector and large and grouped schemes.

Some water-sharing mechanisms are required where water is to be physically diverted or transported from one river basin to another. Normally, inter-basin transfers exist because a physical scheme of channels, dams, tunnels and the like has been constructed. However, such schemes are not always accompanied by a clear definition of the water that is to be taken from one basin and delivered to the other.

A second level of water allocation is within schemes that include a number of water users. Most commonly, this means irrigation schemes, but there are also industrial and urban schemes that involve several users. In these circumstances, the sharing of water between users is conducted at a very different level from the river basin or 'open' situation. Water users, who may be numerous, are embedded within a physical scheme which may be wholly or only partly constructed.

The distribution of water in an irrigation scheme is subject not only to a general concept of volumetric water from the nearest source (river, lake or dam storage), but also to management rules imposed by the operator or owner of the scheme. Various parameters apply within irrigation schemes, not merely the volume of water received (in many, if not most, cases irrigators do not have a concept of a fixed volume but rather a notion of full or part supply to their irrigated area).

Mechanisms for water allocation can be developed at different scales and the scale determines to some extent the appropriate mechanism, as shown in Table 1.

Table 1. Water allocation mechanisms related to scale.

Scale	Mechanisms and activities
National and sub-national (regional, provincial)	• General legislation establishing water rights and obligations of water users • (National) planning (a) for water development, (b) water resource allocation and (c) water resource protection • National agencies for issuing and managing water rights
River basin	• River-basin planning to identify water availability and demand • Establishment of allocation rules at the river-basin level • Consultation mechanisms within the basin • River-basin organisation(s)
Groundwater basin or aquifer	• Aquifer planning to identify water availability and demand and to assess impact of demand on groundwater reserves • Establishment of rules for groundwater extraction and equity considerations • Consultation mechanisms • Water-user organisations

Table 1. (cont'd) Water allocation mechanisms related to scale.

Scale	Mechanisms and activities
Regional or local jurisdiction	• Implementation/oversight of water allocation rules, issue or formalisation of water rights • Issue of water rights to most water users
Headwork water supply schemes	• Operational rules and management decisions which affect the flow of water in rivers
Within irrigation schemes	• Operational rules and management decisions which affect the flow of water • The 'contractual' relationship between scheme operator and irrigator
Within urban water supply systems	• Water distribution network operation (the urban customer plays a passive role except for large, bulk water users)

Table 2 illustrates the different elements of policy development and implementation where a government is attempting to shift water from agriculture to industry and urban water use (a current issue in both China and India and also a trend in Malaysia).

Considerations for Irrigation Schemes

In the case of irrigation, two important water allocation requirements are:

1. the definition, and thereby protection, of the 'bulk' water entitlement at the point or points where the scheme takes in water from the water source (i.e. the river or channel system entering from the river); and
2. the extent to which the operation of the scheme is able to be altered and thereby affect how water is distributed among the irrigators in the scheme, and the mechanisms for agreeing to any such change.

As irrigation schemes have been introduced into areas and among people who have previously not been accustomed to large-scale irrigation infrastructure, those people have had to adapt to participation in the use of physical structures on a scale and with features designed by modern engineering techniques. Their adaptation has been more or less successful, depending on the case. Adaptation has been required in developing countries at two levels:

- the formal management of the scheme, which involves its operation, maintenance and administration, most commonly by an organisation established by the government; and
- the water users themselves who may be given greater or lesser responsibility for the physical aspects of the scheme and the distribution of water within it.

Accompanying the operation and maintenance of irrigation schemes are rules for distributing the water within them. Again, the rules are usually developed in two contexts:

- formal rules established by the scheme operators and managers—such rules may be developed on the basis of the engineering features of the scheme, to maximise the flow and distribution of water according to a theoretical design; and

Table 2. Issues in transfer of water from agriculture to other sectors.

Level	Issues and activities
National or administrative policy	• Adopt national policy for encouragement of transfer of water from agriculture to industry and urban supply
River basin	• Incorporate in strategic planning the transfer of water from agriculture to other sectors—investigate options for achieving this
Local administration	• Define entitlements to water for agriculture such that agreed levels of reliability are provided so that water not used can be accessed by others • Investigate transfer mechanisms, incentives, and efficiency measures
Scheme	• Apply incentives to (a) measure water use, (b) eliminate water inefficiencies and transfer all/part to other uses

- rules developed among the water users themselves after they have been placed in the scheme.

Various problems arise where the engineering design of the scheme leads to a set of rules which do not accord with the way the scheme works in practice or where water users perceive it to require different rules to satisfy their idea of equity. Thus informal rules may develop within, and sometimes competing, the formal rules which are issued by the administering body. This is likely to occur in the case of paddy irrigation because the inter-connection of rice bays requires communal agreement on the disposal and use of water among a group of irrigators.

To illustrate the two-tier aspect of irrigation water allocation, the structure of water rights in an Australian irrigation company is explained in Figure 1.

The Influence of Privatisation

Privatisation has an impact on water rights that may be underestimated. It is well known that various forms of privatisation are being introduced to the water sector. Projects which use or supply water are being considered for commercialisation (government-owned but managed with commercial objectives), corporatisation (government-owned through shareholding and structured like a private company) and, in some cases, outright private ownership. Urban water supply in particular is increasingly privatised.

All forms of commercialisation or privatisation have an impact on water allocation in at least two respects. Firstly, commercial and private operators seek firmer guarantees of access to water. The former direct links with government will not ensure that the water will be made available as required and therefore a legal basis is sought. Where a comprehensive water allocation regime is not in place, the guarantees to private projects usually rest on contractual arrangements with the government in which financial compensation may be payable on case of failure. If a water-allocation regime exists, it may be used more readily (by issuing a right in the form of permit or licence to the company). However, the private sector will push for firm guarantees.

An example is the Snowy Mountains Hydro Scheme in Australia, owned jointly by three governments but being corporatised in readiness for privatisation. The Snowy Scheme (and its financial backers within the governments) insisted that it receive a water licence of 50 years duration with an option to renew for a further 75 years, whereas the standard water licence is issued for 5 years, with renewal for the same period.

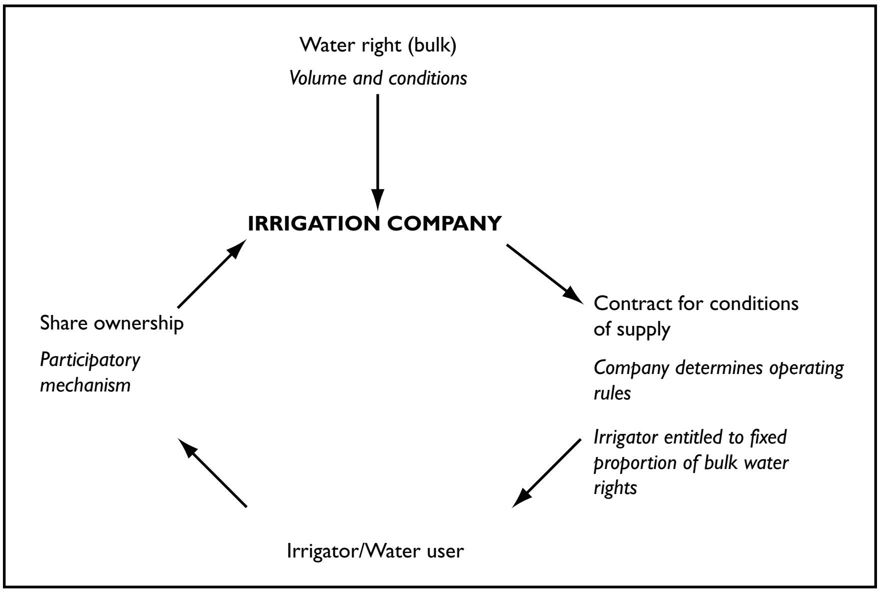

Figure 1. Relationship between water entitlement and irrigator in an irrigation company, New South Wales.

Special legislation was passed for the Snowy Scheme which entitles it to financial compensation if the Government of New South Wales makes any policy change which reduces the value of the Scheme's water licence after the first 5-year period. No such compensation applies to other water users, although recent water legislation (*Water Management Act 2000*, New South Wales) entitles water users to compensation for changes made during the life of 10-year water plans (but not between such plans). The special arrangements for the Snowy Scheme reveal the power of private-sector interests where public schemes are involved.

Where government agencies own and operate water projects, conflicts can be resolved politically and they can be directed to take action accordingly. However, if the same schemes are privatised, the government's ability to intervene is lessened, and unless a framework for directing their activities exists, conflict may be difficult to remove. Further, where water-allocation schemes do exist and the scheme possesses a water right, there must be a robust compliance mechanism with adequate resources. Otherwise, the scheme may ignore the impact it is having on third parties or the environment.

Water Markets and Trading

Water markets need to be considered because they are receiving attention at present. Water trading can occur within a continuum from 'minor' to 'comprehensive'. A minor level of trading would be the seasonal exchange conducted informally between two irrigators, where one allows the other to take his or her water at one time, while the other reciprocates later. This may occur privately and without any formal agency knowledge or involvement. At the other end of the continuum is a formal legislation-based water-market system, such as in Chile, where trading of water rights is conducted through official channels between all types of water use and on a permanent basis (Briscoe et al. 1998).

It is important to understand that water markets only become active where new water cannot be obtained by other means—in other words, scarcity exists. Scarcity may arise because there is already fierce competition for the available water, but may also be imposed by regulation—where the administration refuses to allow further water to be taken. Where a ceiling is placed on further water abstraction, the only means by which new activities can occur is by obtaining an existing water entitlement or right.

Water 'markets' may trade either water rights or water. Where water rights are fully traded, the whole or a part of the right passes from one person to another and may also be activated at a different location and for a different purpose. Unless there are special rules, the conditions that originally applied to the water right will carry over to the new right holder. On the other hand, the holder of a water right may be entitled to receive certain volumes of water within a specified period of time and may sell the right to some or all of that volume to another person, without the water right as such being affected.

Water markets require a water rights foundation. That is why pressure for water markets has been accompanied by developments in water rights. Australia since 1995 is a good example. A national water policy agreement was adopted in 1995 by the Council of Australian Governments which included an intention to facilitate water trading. As a result, most jurisdictions in Australia have since enacted new water legislation covering water rights. In this case, the national policy promoted water trading as a benefit in itself. However, earlier pressure for trading in some States, commencing in the mid-1980s has already resulted in a number of water-trading schemes (Marsden 1999).

A good indicator of the need to consider water trading is the detection of private water exchanges that circumvent rules which do not provide for trading. This shows that the water-use situation requires greater flexibility. It is not necessary to enter immediately into comprehensive markets. In fact, this could be dangerous if the initial trading conditions are not carefully worked out. For instance, if unused water entitlements are allowed to enter a water market, as occurred in New South Wales in the late 1980s, an over-allocation problem can occur or be made worse.

Principles

Economic efficiency is an important economic principle for the allocation of scarce resources, according to which, in theory, the benefit to society of the use of the resource is equal across all sectors. If not, the benefit to society would increase if the water were shifted between sectors or uses (Dinar et al., n.d.). Another principle that has been advanced is equity, which is commonly associated with basic water needs or the idea that all sectors of society should be provided with affordable 'essential' water supplies. Various views of equity arise in cases where governments allocate water rights or make water-management decisions that affect one category of water user in different ways from other categories. Equity is always a factor to be taken into account by agencies allocating water, but in practice it is frequently perceived to be the solution which obtains the widest agreement among water users and other water interests.

Dinar et al. (n.d.) list marginal cost pricing as a form of water allocation, in contrast to water allocation schemes based on public administration, market mechanisms or 'user-based' allocation. The latter can only function within supply schemes that are effectively controlled by a user group, such as within an irrigation scheme or group of schemes.

Role of government

Governments inevitably have an important role in water allocation. Regardless of the governmental system, governments must legislate to establish water rights and generally require the institutional capacity to oversee the relevant legislation. The most market-oriented and property rights-based system cannot exist or function without (a) laws and the maintenance of the laws that govern and define the rights, (b) a register of rights, which requires at least governmental oversight of its management, to provide guarantee of water title, (c) a form of administrative oversight which includes monitoring the taking of water (difficult to accomplish privately on a river-basin scale), and (d) a means for resolving disputes which may, however, be largely given over to a judicial system, as in the western United States.

Other aspects of water allocation would be difficult to establish without governmental involvement or initiative. These include coordination mechanisms for different stakeholders, such as at the river-basin level. Fully private river-basin organisations are unlikely to be created, because so much of their activity is for the protection of the public good. Also included would be the policy on which legislation is based and which guides water allocation decisions by all parties. Note that water allocation is an ongoing function which will never be perfected or concluded.

There are also 'philosophical' reasons, regardless of their merit, why governments are likely to remain involved with water allocation. In most societies, water is regarded by water users and important sectors of the community as a public and 'free' resource. Since water is seen as providing basic benefits for human society, it is virtually impossible for many governments to leave water management entirely to private parties, except in limited circumstances. To the extent that water is seen as a public good resource, there will remain pressure on governments to contribute to the cost of its management. In the absence of measures to provide private sources of funds, it is likely that most governments will continue to fund water-management activities in various ways. Such governmental financial support for water is likely to continue as a political reality, despite growing pressure from developed countries to recognise the need for users to pay. Many activities associated with water allocation fit into the category of activities which governments are expected by society to fund directly. Such activities include technical development, such as the long-term and broad-scale monitoring of water resources, modelling of water sources and associated plan development.

Strengthening institutional arrangements

Based on the earlier discussion, likely important areas for strengthening in water allocation will be the need to:

- broaden the coordination of water uses beyond single sectors, schemes or groups of similar schemes;
- define more accurately the extent of water that may be taken by users and the important conditions, particularly whether the rules need to be adapted for times of water scarcity;
- cater explicitly for benefits which do not result from the taking of water, such as in-stream and in situ benefits—the environment, navigation, fisheries; and
- identify informal and small-scale water uses and protect them from encroachment by large schemes.

An important issue is the potential for water-allocation rules to affect existing and potential future water users differently. For instance, the imposition of a ceiling on the further issue of rights compels new users to purchase water from existing users instead of applying for and taking up a new right issued by the administration. Thus a right issued before the ceiling was imposed may have cost the applicant an administrative fee only, whereas the water user obtaining water after the ceiling is imposed must pay the market value of the water to obtain it. This series of events occurred twice in New South Wales—firstly when the issue of water licences was 'embargoed' on rivers supplied by dams, due to the full take-up of water entitlements in the dams; and secondly, when a 'cap' on further development was imposed on the Murray–Darling Basin through the Murray–Darling Basin Ministerial Council in 1995.

Similarly, where it is concluded that special rules should be introduced to protect the environment or another value, governments may find it more difficult to deal with existing water users than with potential new users. Examples are rules limiting or restricting the rate of abstraction or the capacities of water-supply works, the depth from which groundwater may be pumped, the flow or level at which water may not be pumped or diverted from a river, or the timing of abstraction. If such rules impose financial costs on water users by requiring additional investment or by limiting production, a demand for compensation will be raised immediately.

Another issue is whether water allocation rules in 'normal' conditions should be different from those applying during periods of water scarcity. When all demands can be met, one set of rules and operational guidelines will apply—with the purpose of facilitating supply to all users. When water demand cannot be fully satisfied, a different set of rules must apply. There must be a way to decide how to prioritise the right to receive water. The principles adopted for prioritising access to water may be conditioned by:

- government priorities based on sector-development considerations;
- the protection of supply for essential needs (which should be defined as to what is included or not included);
- the water requirements of the environment;
- pre-existing equity and priorities; and
- new priorities agreed by the majority of the water beneficiary groups in question (this is a task that a river-basin organisation could perform).

Specific principles

Principles for advancing water allocation in regional countries were included in a publication by ESCAP (2000). Some key aspects can be summarised as follows:

Balanced development approach

(a) When introducing or strengthening water-allocation schemes and mechanisms, consider the need to develop simultaneously in the five major areas of support, namely:
    (i) policy and planning;
    (ii) institutional development;
    (iii) legislation;
    (iv) consultation/coordination; and
    (v) resources.
(b) As far as possible, institutional capacity for implementation of water allocation schemes should be developed so that legislation can be applied appropriately without excessive delay after introduction;
(c) The financial resources for water allocation schemes are important for developing and maintaining:
    (i) national and sub-national coordination bodies (such as between ministries which own water-using projects);
    (ii) river basin and major groundwater basin arrangements, including the technical capacity to collect water data and model the water body;
    (iii) systems of licences, permits and authorisation/formalisation of water rights; and
    (iv) compliance.

Central versus local decision-making

(a) The different activities performed at central, regional and local levels of administration need to be identified, with a view to:
    (i) making decisions and taking action as close to water users and benefiting groups as possible; while
    (ii) respecting the hydrologic unit, and its sustainable management.

Pre-existing rights and practices

(a) Legislative schemes for water allocation should be developed in the awareness that various water uses exist and their place in the new scheme should be carefully considered.

Progressive implementation

(a) The implementation of water allocation systems, which include a legal definition of rights to water, should:

   (i) at the initial stages, focus on adoption of the major policies and priorities; and

   (ii) foster mechanisms for coordination and consultation with water users and other beneficiaries of water resources.

(b) In general, the implementation of formal water rights under new legislative schemes needs to be:

   (i) progressive, tackling (a) macro-allocation issues (such as inter-basin water transfers, basin-wide allocation), and (b) specific, critical areas which need rapid attention (provided that water is allocated consistently with other general principles);

   (ii) on the basis of as much data and technical predictive information as possible; and

   (iii) applying effort and resources in proportion to the scale of the problem.

(c) Water legislation should allow for progressive implementation.

Water trading

(a) Water trading can be advanced where:

   (i) pressure for water trading is emerging or already exists (such that water users are circumventing existing rules in order to exchange water or water entitlements);

   (ii) the next step towards freeing up water exchanges is evident and can be negotiated; provided that

   (iii) water-trading rules are developed which protect 'third party' benefits and interests in water, including social values and the environment.

The principles listed above are designed to provide a practical approach to the development of formal water-allocation schemes, avoiding the dangers of unbalanced and impractical development. Two underlying themes are: balanced development—meaning avoiding the introduction of mechanisms which cannot be implemented due to the lack of progress in related areas; and progressive implementation—meaning that mechanisms such as comprehensive water-rights systems and markets need to be designed for stepped introduction at a level that matches the scale and severity of the immediate potential water-conflict issues. Water rights and economic market schemes equivalent to those that exist in developed countries may ultimately be implemented more widely around the world. However, the extensive resources demanded for such schemes, when compared with the immediately perceptible benefits in developing countries and the priority given to water management by governments, caution a progressive and pragmatic approach, so long as long-term goals are kept in mind.

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Institutional Arrangements for Participatory Irrigation Management: Initial Feedback from Central India

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Abstract

This paper presents an overview of the participatory irrigation management system (PIMS) adopted in the States of Madhya Pradesh and Chhattisgarh of India for the effective operation and maintenance of canal networks, and for the timely and equitable distribution of water to the farmers located in the different zones of command areas of water users' associations (WUAs). An in-depth case analysis of 22 WUAs functioning in the Mahanadi Reservoir Project Complex (MRPC) is also presented. An institutional analysis framework was used to diagnose the strengths and weaknesses of PIMS at the macro and micro levels. The current structure of the PIMS has visible control by government at each level of its organisational set-up. The analysis indicates that the government officers—as nominated members in managing committees within the four-tier administrative set up of PIMS—and farmers are in the process of learning and adopting institutional arrangements for managing irrigation systems through collective action. The paper suggests some policy interventions for effective enforcement of institutional arrangements designed in the Farmers' Participation in the Management of Irrigation Systems in Madhya Pradesh, (MP FIMS) Act 1999 (Government of Madhya Pradesh 1999). The overall thrust of the analysis and argument is that better understanding and management of institutional arrangements, and the political and bureaucratic will to share power with the farmers, can help improve not only the performance of PIMS but also promote the goals of sustainable management of scarce irrigation water resources.

Problems in Indian Irrigation

THE green revolution strategy in India has worked exceptionally well in increasing food production and food security, saving forest and land resources owing to improvement in productivity, creating farm and non-farm employment opportunities, and setting the stage for dynamism in the agrarian economy.[1] Achievements of the green revolution were, however, largely confined to the well-endowed and irrigated areas. Investment in canal and groundwater irrigation development has enhanced the productive capacity of land resources which has in turn has enabled the nation to achieve steady agricultural growth.

However, impacts of irrigation systems, particularly of canal irrigation, are besieged with a number of management and environmental problems. Management problems related to the allocation and use of water within the distribution network are exacerbated by poor maintenance and degraded infrastructure. Some of the environmental problems associated with the irrigation systems include waterlogging, salinity and weed infestation. It has been shown that the economic gains from surface irrigation in many projects are not commensurate with the large public investments and subsidies given to the farmers (Ahmad and Singh 1986; Mishra 1986; Chambers 1988; Gulati 1989; Vaidyanathan 1994; Dhawan 1995; Marothia 1997b).

It is not that the irrigation-induced land degradation occurred in the absence of technologies that could have prevented them. For example, studies

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1. For a fuller discussion of the problems in Indian irrigation, see Marothia (1997b).

have clearly suggested that technologies for reclamation of saline and waterlogged lands are financially viable at the individual farm level (Joshi and Agnihotri 1982; Joshi et al. 1987; Tyagi et al. 1995). Community approaches through farmers' participation can effectively manage the canal system and, in turn, problem soils (Joshi 1997). However, research has shown that the conditions and the institutional foundation arrangements for community-approach collective actions are generally absent, which means community approaches do not succeed (Shah and Ballabh 1986; Marothia 1993, 1997b, 2001a,b,c).

To date, government interventions to promote the flow of reclamation technologies have been largely in the form of input support and extension of subsidies. However, these interventions are targeted towards individual farmers, whereas the problem associated with canal irrigation and its management go beyond the boundaries of private property structure. Farmers' cooperation can play a crucial role in managing the problem of irrigation-induced land degradation and in exploiting the full potential of irrigation (Datta and Joshi 1993), but requires appropriate technological and institutional arrangements (Marothia 1993, 1997b, 2001a; Joshi 1997). These institutional arrangements can effectively transform the private incentive to a collective one so that the canal water can be managed as a common pool resource.[2] These arrangements may cover rehabilitation of existing canal irrigation systems, operation and maintenance of the systems, conjunctive use of surface and groundwater, design of cropping patterns, allocation and scheduling of water, enforcement (or changes, if needed) of the rules, and regulations governing access to irrigation water by individual farmers (Veeman 1978; Chambers 1988; Wade 1988; Singh 1991; Shah 1993; Moench 1994; Saleth 1994; Vaidyanathan 1994, 1996; Agarwal and Narian 2001; Deshpande and Jyotishi 2001; Joshi 2001; Mahapatra and Rajput 2001; Rathore 2001).

Until recently, the decision-making environment and incentives facing farmers and irrigation officials were not dealt with sufficiently. Many researchers and policy-makers have suggested privatisation or strengthening state control of the canal irrigation network as possible solutions to arrest degradation of the system and for effective water distribution system in the command areas. However, government or state control over canal irrigation water distribution has had a relatively weak record (Marothia 1993, 1997b). In turn, resource management under common and private property regimes has increasingly come to be seen as a better alternative to a state management regime (Marothia 1992, 1993, 1998, 2001a; Singh 1994; Townsend and Pooley 1995). Dissatisfaction with traditional failure of 'pure' community irrigation management and 'pure' government control has led to great interest in participatory irrigation management to achieve a self-governing system. Local communities may be able to provide input into the design and administration of institutional arrangements that are workable with the least transaction costs. The local communities of farmers have cumulative traditional knowledge about the nature and extent of weeds and grasses responsible for blockages in the drainage network in the command area under their jurisdiction, and the traditional water distribution pattern, that may be useful in designing effective institutional arrangements. Locally enforced institutional arrangements may have the advantage of greater acceptability, and hence may face less resistance in implementation than institutional arrangements designed by external agencies and imposed externally on the resource users in a particular ecosystem (Singh 1994; Townsend and Pooley 1995; Marothia 1997a, 2001a,b).

In recent years, particularly in the 1980s, several developmental programs for water resource development have been introduced and a few of them have been managed under distributed governance or a shared management system (Marothia 2001a). In these projects, local communities/resources users groups and the State or local government shared the responsibility of managing water resource distribution within a command area beyond the outlet of the water distribution network, by combining appropriate institutional skills of local resource users/local committees and the technical, administration and financial resources available from the States. However, attempts to strengthen the role of water users' associations in India have had mixed success. The key reason for the success of some water users' associations may be attributed to effective design of technical and institutional arrangements for the main canal system,

2. See case studies reported in Bromley (1992) for problems associated with common property rights and methods of diagnosis of common property resource problems. Most of the case studies reported in that volume used the Oakerson (1986, 1992) model to understand the problems of common property resources.

below the outlet, and at the community/farm levels (Bromley et al. 1980; Bromley 1982; Pant 1986; Chambers 1988; Marothia et al. 1989; Patil and Lele 1996; Kolavalli 1997; Marothia 1997a, 2001a; Raju 1998). A large number of irrigation development programs in India failed or could not yield anticipated outcomes due to a lack of understanding on the part of the researchers, administrators, and planners about the issues related to distributed governance or shared management and institutional arrangements and their application in the socioeconomic network of village life (see Marothia 1993, 1997a; Gupta 1995 for the importance of local institutional arrangements in managing local-level institutions).

In this paper, the institutional economics framework is used to discuss problems in the management of Indian irrigation. The paper argues that canal irrigation can effectively be managed with adequate understanding and investment in evolving appropriate institutional arrangements. The outline of the paper is as follows. In the next section, an institutional economics framework for analysing common property resource management is presented, which is used to provide a background for understanding the irrigation management problem. This is followed by a description of the participatory irrigation management system (PIMS) adopted in the States of Madhya Pradesh and Chhattisgarh. A case study of the performance of the PIMS is then presented, which is based on a field study of 22 water users' assocations (WUAs) in Chhattisgarh. An institutional analysis framework is used to diagnose strengths and weaknesses of the PIMS at the macro and micro levels. In the final section, policy interventions are suggested that might provide some meaningful feedback to the PIMS committees to make necessary adjustments to their functioning in both the States.

An Institutional Economics Perspective on Property Rights

The key concepts used in this paper to understand the participatory irrigation management systems are institutional arrangements, property rights structures and authority systems. These concepts have their roots in institutional economics (Commons 1950; Bromley 1991; Ostrom 1992). The role of institutional arrangements is extremely important in management of irrigation as a common pool resource under any property rights regime (state, private, community and open access or no regime). Institutions are defined as 'collective action in control, liberation and expansion of individual action' (Commons 1931, p. 649). Institutions include laws, constitutions (i.e. 'laws about making laws'), traditions, moral and ethical structures, and customary and accepted ways of doing things (Commons 1924, p. 124). Institutional arrangements are applied to resolve conflicts of interest of many individuals with diverse interests and preferences. To maintain a coordinated flow of action and transactions in the conduct of any going concern, society adopts working rules that define person-to-person relations with respect to property (Commons 1931; Gonce 1971). Institutional arrangements or working rules effectively indicate the cause, effect or purpose—essential for collective action. Working rules also indicate what individuals can, must, or may or may not do, enforced by collective sanctions (Commons 1931, p. 650). Collective action, as well as individual action, is influenced by scarcity. In the face of scarcity, according to Commons (1934), self-interest breeds conflict and disorder. Ownership becomes the foundation of an institutional framework because ownership interacts with scarcity to create conflicts of interest which are 'predominant in transactions'. But transactors are mutually interdependent as well as conflicting. Because of this mutual interdependence, the alienation and acquisition of rights of future ownership of resources among individuals would be negotiated between the parties concerned according to the working rules of society, thus creating a 'certain security of expectation' or 'order' (Commons 1934). Thus rights are relative, evolutionary and subject to change or limits as per the needs or values of power relationships and society (Commons 1934).

Thus, institutions express a society's value system and give it effect in the form of working rules. In other words, institutions or working rules order relationships among individuals within society and structure incentives in human exchange, whether social, economic or political (North 1990; see also Dasgupta and Maler 1994; Williamson 1994; Weimer 1995; Drobak and Nye 1997). Property rights institutions are part of 'cultural capital' by which resource user communities convert 'natural capital' (resources and ecological services) into 'human-made capital' or the inputs of production (Berkes and Folke 1992, 1994). Cultural capital includes social and institutional capital (see Coleman 1988; Ostrom 1992). Institutions or cultural capital include how people in any society view the natural resource use, values and ethics including customs/norms, and religion along with culturally transmitted knowledge (Folke and Berkes 1995). Institutions are arrangements for interdependent decision-making in reciprocal and joint efforts. The capacity of individuals to form stable expectations about the behaviour of others by knowing the working rules is a basic condition for the functioning of any organised going concern. The principle of working rules is critical to form social relationships and choose alternative policies and governance in managing common property resources in general and canal irrigation in particular.

The nature of institutional arrangements defines the extent of property regimes over land, water and related resources. A property regime is a system or a set of institutional arrangements or working rules of rights and duties characterising the relationship of co-users to one another with respect to a specific natural resource (Bromley 1991). Property rights in resources exist either under a State property regime (where the secure claim rests with government), private property regime (claim rests with individual or corporation), common property regime (individuals have claims on collective goods as members of organised groups), or open access (or no property regime with no secure claims) (Bromley 1991). The basic requirement for any property regime is an authority system (for example, central or state local village governments, Panchayats, resource development committees, user groups) that can guarantee the security of expectations for the rights holders (resource users). When the authority system breaks down, a particular resource regime starts degenerating. In such a situation, new institutional arrangements are used to define the resource regimes over natural resources and the authority systems protect the interests of those (resource users) holding the rights under a particular regime.

Natural resources, like land and water, are managed and controlled through technical and institutional arrangements. The technical arrangements help in hydrological and engineering design of canal/distribution/pipe outlets field channels, and water control devices etc. Technological components, in other words, define how water resources can be used as factors of production. The institutional arrangements define who can control the resources and how the techniques are applied. Technological and institutional arrangements must complement each other if resources are to be used efficiently and sustainably (Gibbs and Bromley 1989).

It is important to recognise that governance can be shared among States, communities and private interest groups in various ways. In other words, distributed governance is the extended version of the standard regimes of property rights (state, common and private property, open access). Distributed management systems involve sharing authority among different groups/agencies at different decision-making levels (Townsend and Pooley 1995). Distributed governance involves the external institutional arrangements among government and local communities or resource users as well as internal institutional arrangements within local community institutions or resource users. Government, local communities and private parties utilising common pool resources each bring different interests, capabilities and understanding to the resource management process (Townsend and Pooley 1995). These alternative institutional perspectives shape the decision-making process among government, local resource users' communities, and members of local community for managing a resource by converting unorganised structures into the organised ones (Marothia and Phillips 1985).

An external governance structure has essentially three alternatives of management systems (Townsend and Pooley 1995), namely, *rights-based management* (the government grants usufructuary rights to individual resource users/parties under well-specified constraint conditions, assumes the role of monopoly over the resource base, and retains all responsibility/authority for conservation decision), *co-management* (the government and local communities share ongoing responsibility for decision-making over all or most of the resource management decisions) and *contracted management* (a large part of the decision-making process is transferred to local bodies). These systems have been functional in various parts of India in general and Chhattisgarh in particular to manage common property resources, including canal irrigation systems. These alternative management systems have their inherent strengths and weaknesses (see Marothia 1996a,b, 1998 for evolution process of external institutional arrangements in managing water and other common property resources in the states of Madhya Pradesh and Chhattisgarh).

Three alternative internal institutional arrangements (Townsend and Pooley 1995) have been closely associated with the concept of distributed governance: *self-organising institutions* (institutional and organisational decisions remain with local communities and the government may use the institutional building capacity to support and gain strength from self-organisation); *communal management* (to reduce the existing authority of state and vest more localised interest); *cooperative management* (membership is limited with well-defined working rules for collective governance) *and corporate governance* (under which the owners and shareholders of the corporation would operate under governance rules typical of private corporations (see Townsend 1995; Townsend and Pooley 1995 for detailed analysis of external and internal institutional arrangements)). The degrees of authority that government could grant to local organisation varies with the internal governance structure (see Marothia 1993, 1997a for the importance of internal institutional arrangements in managing village commons like common wastelands, water bodies and small irrigation tanks). If management is to be most effective and efficient, two features should characterise distributed management—firstly, clearly defined institutional arrangements for local community and government. These minimise the potential for prolonged and costly disagreements among resource users' groups and government administration. Secondly, decision-making structures should be shared at different levels of administration so that the costs and benefits of any decision are internalised within some cohesive decision-making unit (Townsend and Pooley 1995).

To understand better how these parameters affect governance in the irrigation system, one must systematically analyse the contextual attributes that shape various transactional (action) situations. Drawing on literature in economics and economic history, political science, law, business, game theory, and anthropology, scholars have developed an institutional framework that identifies key attributes of typical situations facing resource users and decision-makers in various circumstances (Kiser and Ostrom 1982; Oakerson 1986, 1992; Ostrom 1986, 1992; Tang 1992). Various physical, technological, community and institutional attributes may affect the outcome directly or though collective action situations (or transaction situations) and patterns of interactions. The interrelationships or resource attributes, attributes of the community, decision-making arrangements, and patterns of interactions shape various action situations and can ensure efficient, equitable and sustainable outcomes in managing common property resources. Researchers have recently used the Oakerson (1986, 1992) model and its derivative forms for analysing common property resources in various parts of the world and in the Indian context (see case studies reported using the Oakerson model in Arnold and Stewart 1991; Bromley 1992; Ostrom 1992; Tang 1992; Marothia 1993; Singh 1994; Floke and Berkes 1995; Singh and Ballabh 1996).

Participatory Irrigation Management in Madhya Pradesh and Chhattisgarh

The government of Madhya Pradesh passed a bill in 1999 which transferred the management of the State irrigation canal network to its beneficiaries with financial and technical support. The Act is known as *Madhya Pradesh Sinchai Prabandhan Me Krishakon Ki Bhagidari Adhiniyam 1999* (Farmers' Participation in the Management of the Irrigation System in Madhya Pradesh, MP FIMS Act 1999). The objective was to transfer management of the irrigation system to water users' associations (WUAs) by June 2000 after completing minimum rehabilitation works in the canal network system. The PIMS has unique features to ensure the greater participation of farmers under the distributed governance system of irrigation management. The external and internal institutional arrangements designed in the Act for implementation at the field level include transfer of power to manage State assets, creation of new autonomous institutions as legal entities, and definition of management areas on a hydraulic basis. Equity is promoted within the structure of WUAs by introducing the concept of territorial constituencies. That is, all landholders in possession of land in an irrigation system have equal voting rights with elections held by secret ballot. The WUAs have functional and administrative autonomy and freedom to raise resources and resolve disputes. Procedures for taking up works have been simplified. The WUAs have five-year tenure and the Department of Water Resources Department (WRD) is made fully accountable to the WUAs. The WUAs retain the right to recall an elected member after one year, and there are provisions for social auditing and an annual accounts audit.

The PIMS involves revolutionary legislation promoting a total change in the management of irrigation systems through farmers' organisations (FOs). FOs include WUAs at the primary level, distributary committees at the distributary level, and project committees at the project level. All minor irrigation schemes have only one tier of FO (WUA), while the medium irrigation schemes have a two-tier structure (WUAs and the Project Committee), and the major irrigation projects have a three-tier structure (WUAs, distributary committees and project committees). The functions and responsibilities of the WUAs under the PIMS are summarised in Table 1. For a fuller description of the organisational structure proposed and implemented under the PIMS Act, see Appendix 1.

Performance of PIMS and WUAs

In this section, the performance of the PIMS is examined using a case study of Chhattisgarh[3] State. The case study was confined to the 22 WUAs functioning in Mandhar Branch Canal (MBC) of Mahanadi Reservoir Project Complex (MRPC). The location and other characteristics of this canal are illustrated in Figures 1 to 3. MBC is located in the middle section of Mahanadi Main Canal, 49 km from the Mahanadi Main Canal near village Kodapaar (Abhanpur). The total length of the canal is 52 km. It has 23 distributaries which cover a canal distribution network of 3,344 km. Nearly 38,000 ha is irrigated through the distributaries of the MBC. The canal covers 185 villages in the Abhanpur, Arang and Dharshiwa blocks of the Raipur district. Operation and maintenance work of the MBC and its distributaries and minors under the supervision of WUAs has been carried out with financial assistance provided to WUAs under participatory irrigation management (PIM). To assess the WUAs' performance within a framework of institutional analysis, 22 WUAs (Table 2) were selected from the MBC of the MRPC. To analyse the perception of the members of the managing committee of WUAs, opinions were gathered during group meetings. In the group meetings, discussion was organised according to pre-designed issues/questions related to awareness of institutional arrangements designed in the PIM Act and the collective outcome of the institutional arrangements. For this purpose, 22 presidents (one from each WUA), 44 elected members (2 from each WUA), and 32 nominated members (22 sub-engineers and 10 agricultural extension officers) were interviewed in the groups and common consciences were recorded. Most of the meetings were conducted in the different offices of MRPC located in the Raipur district of Chhattisgarh State. To cross-check the responses of the members of the managing committee, a field walk was undertaken in all the WUA areas. The group meetings and field walks were undertaken in the last week of March and first week of April 2001, and the questions discussed are shown in Table 3. The perceptions of members (elected and nominated) were used in analysing the performance of WUAs.

Approach adopted in the case study

To analyse the strengths and weakness of PIM and to suggest measures to improve the distributed governance through participatory management, we have basically used the institutional framework developed in a number of analytical models (Oakerson 1986, 1992; Gibbs and Bromley 1989; Blaikie et al. 1992; Ostrom 1992; Tang 1992; Townsend and Pooley 1995). PIM fits well within a framework of a self-governing system of internal institutional arrangements, and has been used in other Indian studies of governance systems for managing common pool resources (e.g. Arnold and Stewart 1991; Singh 1992, 1994; Marothia 1993, 1996a,b,c, 2001a; Singh and Ballabh 1996).

[3] The State of Chhattisgarh was established in November 2000, and was carved out from Madhya Pradesh. The State comprises 16 districts and covers a total area of 135,100 km2. The entire State predominantly falls in the rice agro-climatic zone. The Mahanadi Reservoir Project Complex (MRPC) is one of the major irrigation developments in the State and was first established in 1927. The new State has continued the organisation of the Water Resources Department it inherited from Madhya Pradesh, including the new participatory irrigation management Act.

Table 1. Changes in institutional arrangements after participatory irrigation management (PIM).

Goals for the water users' associations (WUAs) under the PIM system

Management of water distribution and irrigation system:
Management, maintenance and distribution of water;
Crop and cropping system;
Demarcation of irrigated area;
Collection of water tax and management of financial resources;
Financial and social audit;
Transparency in work;
Settlement of disputes in command area.

Financial empowerment:
Management of funds subject to approval of competent authority;
Authorised level of technical sanction;
Financial power and release of funds: through executive (chief) engineer to WUAs, with work to be conducted by WUAs.

Preparation of work plan:
Solution for identified works;
Preparation of proposal;
Work notification;
Transparency in execution of work;
Work measurement and maintenance of work record.

Listed functions and responsibilities

Water users' associations (WUAs):
To prepare and implement rotational irrigation schedule as approved by Distibutary Committees;
To prepare and carry out maintenance work of irrigation system with the funds of WUAs;
To regulate the use of water among various pipe outlets;
To maintain required records, conduct audits, and raise funds;
To conduct general body and managing committee meetings, and assist in conduction of election of managing committee;
To abide by decisions of Distributary Committees and Project Committees.

Distributary Committees (DCs):
To prepare operational agricultural plans at the beginning of each irrigation season;
To prepare maintenance plans for irrigation systems and execute these with the available funds;
To regulate the use of water and resolve conflicts among WUAs;
To maintain a register of inventories of irrigation systems, accounts and other records of WUAs;
To conduct general body meetings and managing committee meetings, and assist in conduction of election of managing committees.

Project Committees:
To approve operational plans for the maintenance of irrigation systems;
To maintain records of inventories of WUAs and DCs;
To resolve conflicts of DCs;
To conduct regular audits;
To conduct general body meetings as prescribed in the Act.

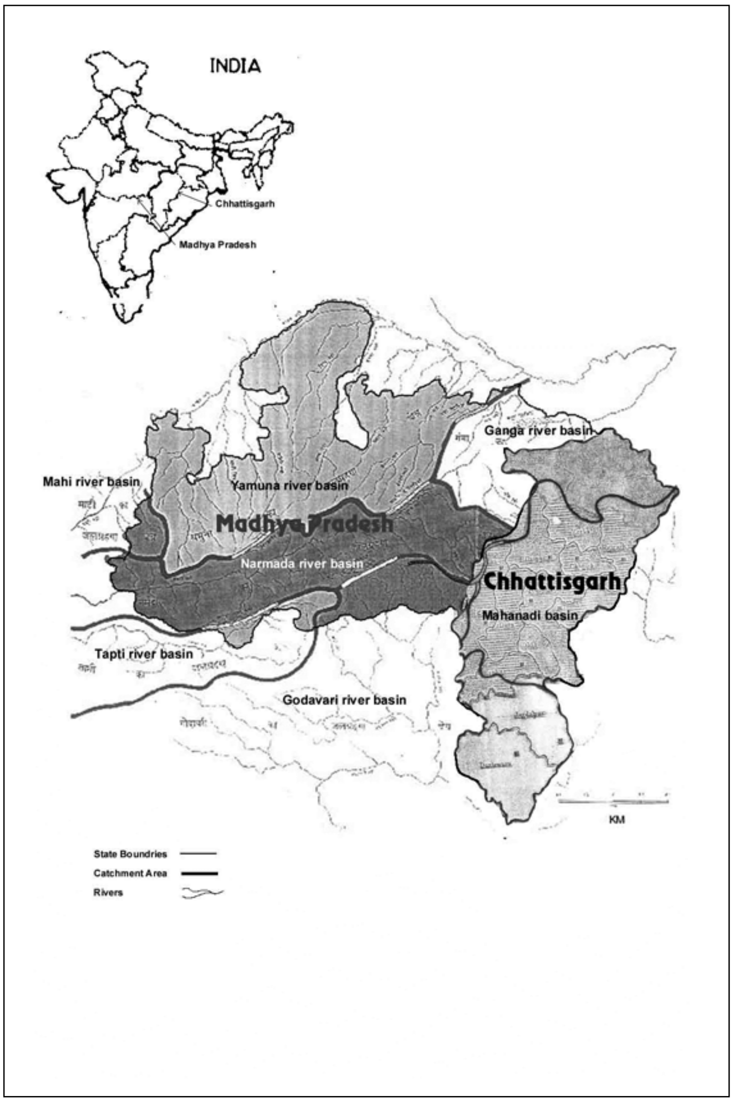

Figure 1. The river basin of Madhya Pradesh and Chhattisgarh.

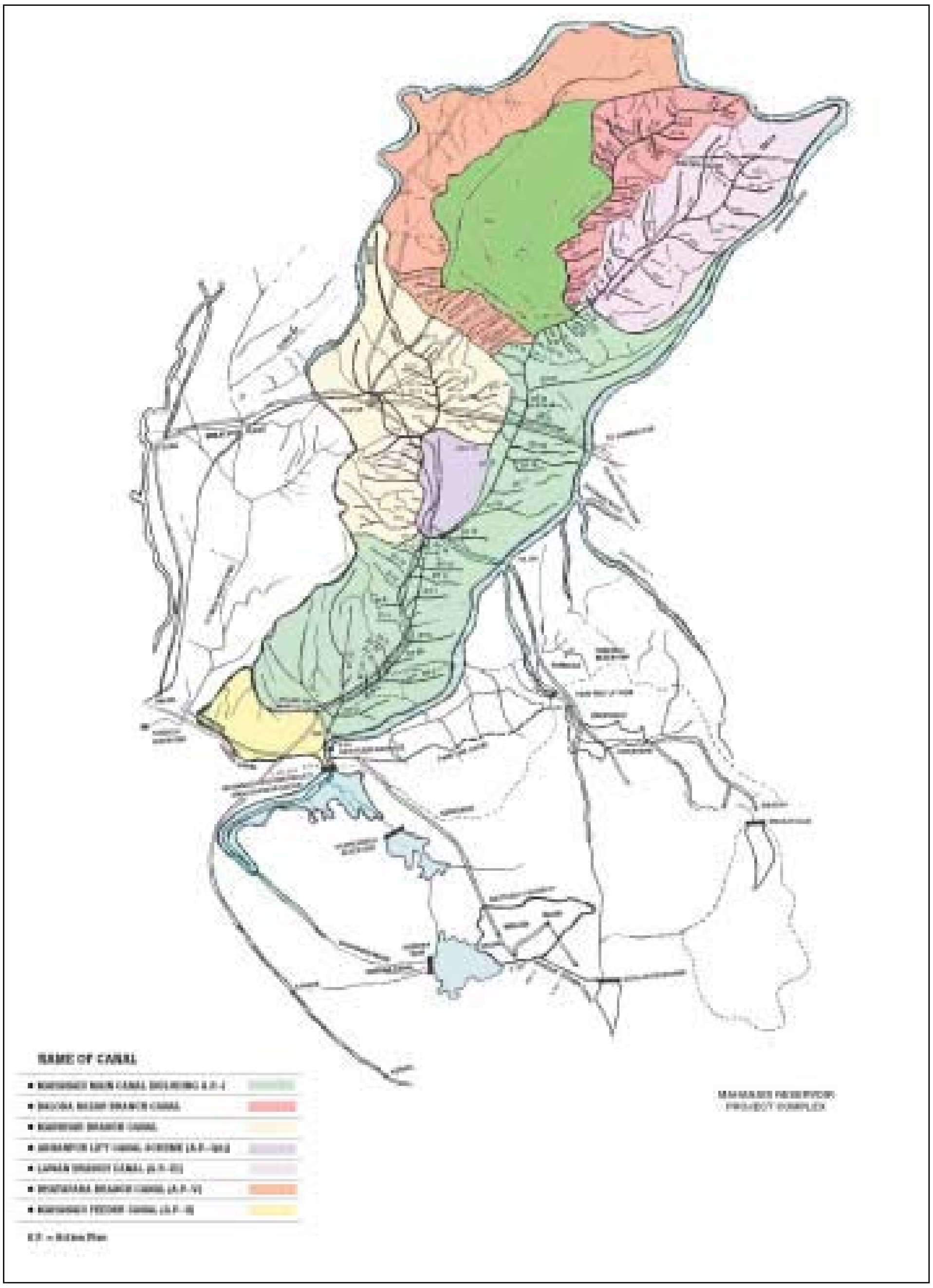

Figure 2. Mahanadi Reservoir Project Complex.

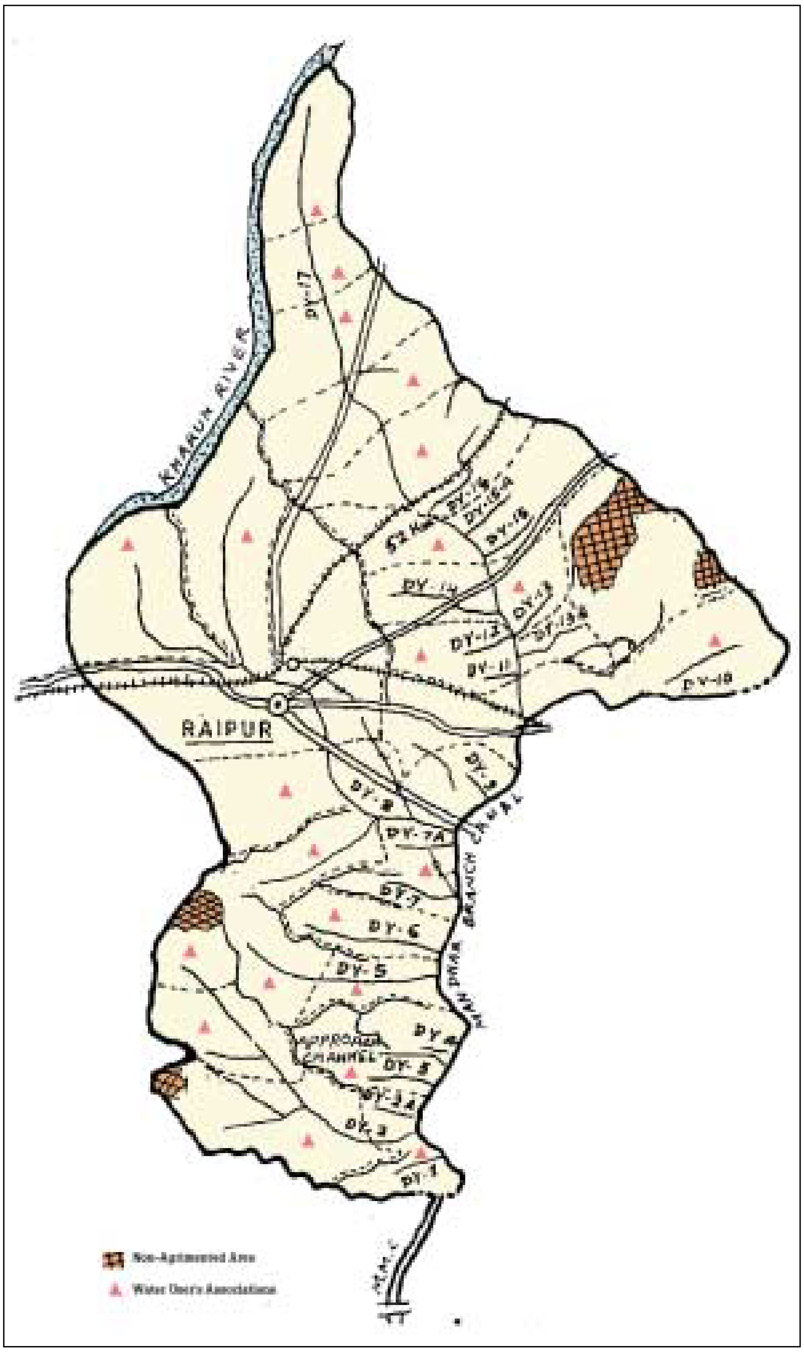

Figure 3. Network of water users' associations in Mandhar Branch Canal.

Sustainable management of canal irrigation water largely depends on the physical and technical attributes of irrigation system, the irrigators' characteristics in terms of social and economic status, location along the water course, dependence on canal water, local knowledge of irrigators and technology, pattern of institutional arrangements, property rights regimes or irrigation governance structures, and authority systems. A framework of the attributes affecting the management of irrigation systems in India is presented in Figure 4. These attributes usually combine in a configurational manner. That is, to examine the effect of one attribute, one must know what other attributes are also in effect. A change in one attribute may alter the way the entire configuration operates, thus creating quite a different action situation. This principle implies that when one tries to explain the performance for a various level of canal irrigation management, one must be aware of the interrelationship among the internal and external arrangements involved in relation to canal water and irrigators, and show how these assumptions, attributes and outcomes are related to one another within the conceptual framework for analysing PIM.

Table 2. Details of the water users' associations (WUAs) in the case study area.

Name of WUA	Blocks	No. of villages covered	No. of territorial committees	Total no. of farmers	Command area (ha)	Water availability (A/M/S)[a]
Belar	Abhanpur	10	10	2,417	2,272	A
Bhrenga	Abhanpur	8	8	1,115	1,500	S
Sharkhi	Abhanpur	5	10	2,632	1,924	M
Khorpa	Abhanpur	10	10	1,737	1,975	S
Parsada	Abhanpur	7	6	1,238	1,224	S
Tekari	Abhanpur	7	6	1,684	1,441	M
Shishanpari	Abhanpur	6	8	1,743	1,967	M
Boryakala	Abhanpur	10	10	2,320	2,081	M
Mana	Dharsiwa	10	10	2,606	1,980	M
Dunda	Dharsiwa	12	10	2,225	1,786	S
Urla	Dharsiwa	6	6	1,713	1,946	S
Kurud	Dharsiwa	8	8	2,263	1,701	S
Hirapur	Dharsiwa	8	8	2,513	1,008	S
Dharsiwa	Arang	10	10	2,263	1,506	S
Mohdi	Arang	8	8	2,252	1,417	M
Sivni	Arang	10	10	3,133	1,640	S
Mandhar	Arang	8	8	2,306	1,919	M
Semariya	Dharsiwa	10	10	2,528	1,766	M
Tulsi	Dharsiwa	8	8	2,715	1,706	S
Nardha	Dharsiwa	10	10	2,499	1,866	S
Pandar Bhata	Dharsiwa	6	6	1,325	1,554	S
Kura	Dharsiwa	8	8	2,530	1,056	M
Total		185	188	47,757	37,235	
Average		8	9	2,171	1,693	

[a] A = adequate; M = moderate; S = scarce.
Source: compiled from various documents of the Water Resources Department, Government of Chhattisgarh.

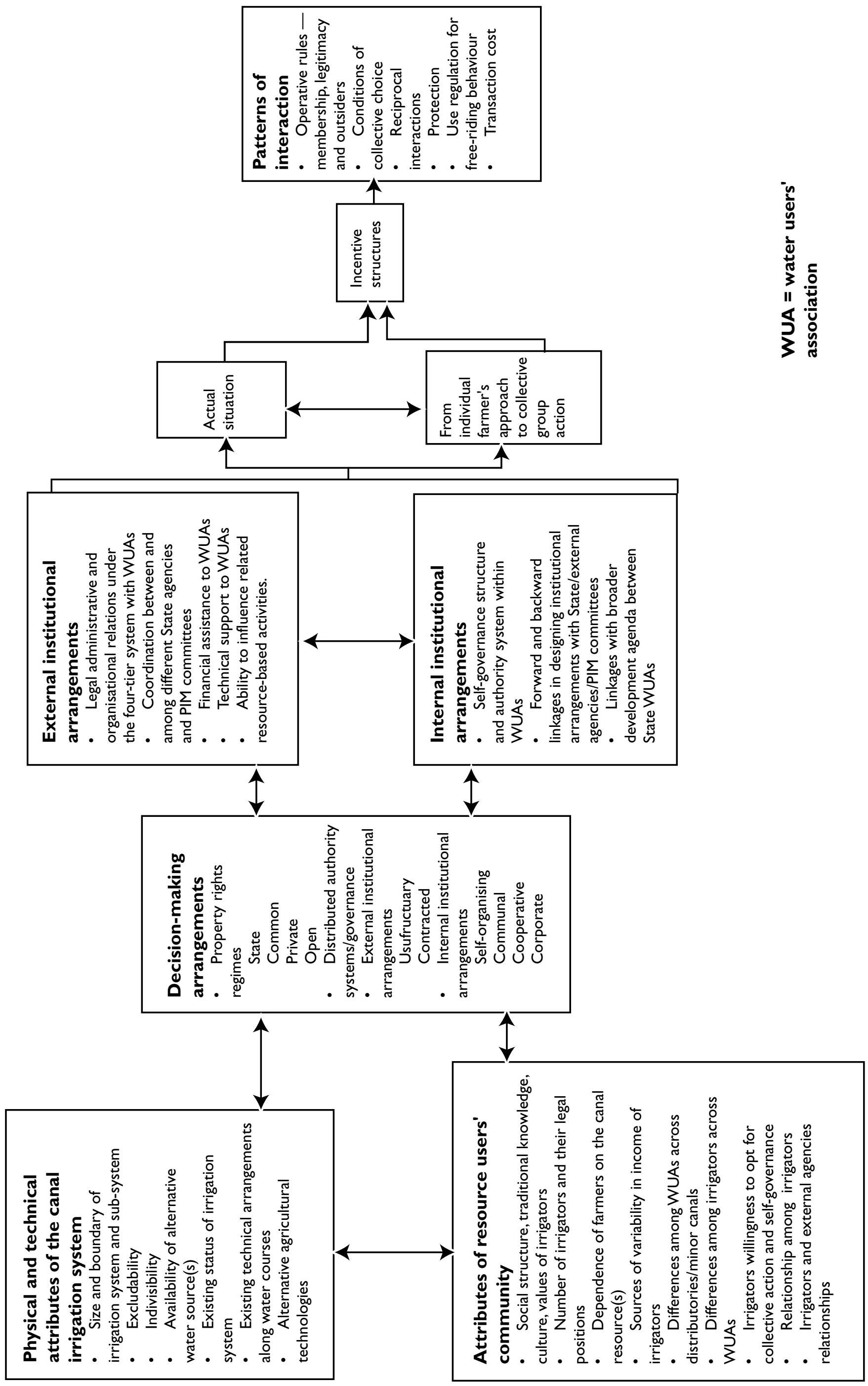

Figure 4. Conceptual framework for institutional analysis of participatory irrigation management (PIM).

Table 3. Issues discussed during the field walk.

- Condition of sub-branch of minor canal and quantity of siltation and weeds.
- Flow of distributary or sub-branch of minor into the different points.
- Destruction of bunds.
- Point of water seepage and assessment by eye of extent of water seepage.
- Identification of permanent structure and its condition.
- Damage in the irrigation system due to poor management.
- Condition of measuring instruments.
- Damage at different levels of the irrigation system, if any.
- Siltation, weeds and erosion in the drainage system.
- Awareness about rules in use listed in the participatory irrigation management (PIM) Act.
- Support from nominated members.
- Anticipated negative and positive outcomes of PIM in the short and long term.

Each component of the conceptual framework has sub-sets of attributes. Each set of attributes is related to the others. For example, characteristics of the irrigation system, WUAs, irrigators and institutional arrangements, alternative property regimes, and distribution of the authority system collectively affect external and internal institutional interaction patterns. Characteristics of the irrigation system and irrigators, and members of managing committees can affect the performance directly or through patterns of interactions between external and internal institutional arrangements. The first two attributes of the framework can be treated as exogenous variables and the institutional arrangements as endogenous in the short run. Irrigation management structures choose strategies in the pattern of interactions between the State and WUAs. These choices reflect the combined set of constraints and opportunities found in technical and/or physical attributes of an irrigation system and the characteristics of irrigators/farmers and the institutional arrangement associated with its management. These collective choices form some pattern of interactions. The interaction results in the outcomes, and these outcomes are subject to evaluation. In the case of a negative outcome, backward linkages have to be traced to determine the relationships between the water resource and external and internal institutional arrangements and to modify the institutional arrangements for achieving a PIMS under distributed governance. The conceptual framework suggested herein also has a dynamic application.

In the long-term analysis, institutional arrangements are exogenous and their effects could be iteratively assessed on interactions between external and internal arrangements and outcomes (see Oakerson 1986, 1992; Tang 1992). For example, in the case of canal water, many changes may occur in the physical and technical nature of the resource, and the outcome project can affect the patterns of interactions among the different committees (apex, project, distributary and different associated departments) and WUAs, and between WUAs and farmers. In such cases, institutional arrangements should be modified by WUAs and farmers. It is a continuous adjustment process of shaping institutional arrangements for PIM. To this end, we now discuss the concept, organisational structure, functions and responsibility of managing committees working under the four-tier administrative set-up to implement and enforce PIM.

Using the conceptual framework of institutional analysis detailed in Figure 4, the performance of PIMS and WUAs has been analysed and evaluated. The information used for assessing the performance of PIMS and WUAs is based on the information generated through field walks and meetings and group discussions with members of managing committees, including government-nominated members and engineers-in-chief, superintendents, and executive and assistant engineers. Most of the issues discussed during the field walk pertained to the awareness and effectiveness of technical and institutional arrangements. The sub-attributes of technical and institutional arrangements are given in Tables 4 and 5.

Physical, technical and community attributes

The physical and technical attributes of the irrigation system linked with the command area above and below pipe outlets within the jurisdiction of a particular WUA together with the characteristics of irrigators affect the performance of WUAs in terms of the adequate and equitable supply of water. Performance of WUAs was assessed using the physical attributes including the size and boundary of MBC and its distributaries, the command area of WUAs, the pattern of water supply and availability, the availability of alternative water sources in the command area of

Table 4. Physical attributes of Mandhar Branch Canal.

Name of canal/ distributary	Total length (km)	Position of canal/distributaries (head/middle/tail)	Rate of discharge (L/s.ha)	Name of water users' association
Mandhar Branch Canal	52.50	Middle of main canal		
Distributary No.1	1.50	Head	0.78	Belar
Distributary No.1A	1.30	"	"	Belar
Distributary No.2[a]	16.50	"	"	Bhrenga, Khorpa, Parsada
Minors of Dy.No.2	24.80	"	"	Bhrenga, Khorpa
Distributary No.2A	2.20	"	"	Belar
Minors of Dy.No.2A	2.30	"	"	"
Distributary No.3	4.70	"	"	Sharkhi
Minors of Dy.No.3	2.70	"	"	"
Distributary No.4	1.50	"	"	Sharkhi
Distributary No.5	12.70	Middle	"	Tekari, Shishanpari
Minors of Dy.No.5	1.50	"	"	"
Distributary No.6	7.40	"	"	Boryakala
Minors of Dy.No.6	6.00	"	"	"
Distributary No.7	3.00	"	"	Mana
Distributary No.7A	4.50	"	"	Mana
Distributary No.8[a]	30.00	"	"	Dunda, Urla, Kurud, Hirapur
Minors of Dy.No.8	50.00	"	"	Dunda
Distributary No.9	3.00	"	"	Mana
Distributary No.10[a]	18.00	"	0.78	Dharsiwa
Minors of Dy.No.10	8.00	"	"	Dharsiwa
Distributary No.11	1.00	"	"	Mohdi
Minors of Dy.No.11	1.00	"	"	"
Distributary No.11A[a]	7.30	"	"	Sivni
Minors of Dy.No.11A	–	"	"	"
Distributary No.12	2.40	"	"	Mohdi
Minors of Dy.No.12	–	"	"	"
Distributary No.13	3.00	"	"	Shivni
Distributary No.14	5.00	"	"	Shivni
Distributary No.15	5.00	Tail	"	Mandhar
Minors of Dy.No.15	3.00	"	"	"
Distributary No.15A	1.50	"	"	Mandhar
Distributary No.15B	0.50	"	"	"
Distributary No.16	6.50	"	"	Semariya
Minors of Dy.No.16	2.00	"	"	"

[a] These distributaries have water scarcity.
Notes: In all distributaries and minor canals, water control outlets are fixed and functional.
The area irrigated during the first irrigation is 60% (period lasting 25 days) and in second and third is 100%
Irrigation is from August to October, the total command area is 37,235 ha.
Source: Water Resources Department, Government of Chhattisgarh.

Table 4. (cont'd) Physical attributes of Mandhar Branch Canal.

Name of canal/ distributary	Total length (km)	Position of canal/distributaries (head/middle/tail)	Rate of discharge (L/s.ha)	Name of water users' association
Distributary No.17[a]	22.50	"	"	Tulsi, Nardha, Pandarbhata
Minors of Dy.No.17	29.00	Tail	"	Kura
Total:	346.80			

[a] These distributaries have water scarcity.
Notes: In all distributaries and minor canals, water control outlets are fixed and functional.
The area irrigated during the first irrigation is 60% (period lasting 25 days) and in second and third is 100%
Irrigation is from August to October, the total command area is 37,235 ha.
Source: Water Resources Department, Government of Chhattisgarh.

Table 5. Elected representatives of the water users' associations (WUAs).

Name of WUA	Total number of elected members		Vacancy	Sub committees		WRD[a]	Tenure of president/ members
	E	U		Managing	Financial		
Belar	6	4	0	1	1	1	5
Bhrenga	1	5	2	1	1	1	5
Sharkhi	2	6	2	1	1	1	5
Khorpa	1	9	0	1	1	1	5
Parsada	1	3	2	1	1	1	5
Tekari	1	3	2	1	1	1	5
Shishanpari	1	6	1	1	1	1	5
Boryakala	0	10	0	1	1	1	5
Mana	0	10	0	1	1	1	5
Dunda	5	2	3	1	1	1	5
Urla	0	3	3	1	1	1	5
Kurud	0	8	0	1	1	1	5
Hirapur	0	1	7	1	1	1	5
Dharsiwa[b]	1	6	3	1	1	1	5
Mohdi	7	1	0	1	1	1	5
Sivni	0	10	0	1	1	1	5
Mandhar	3	5	0	1	1	1	5
Semariya	4	6	0	1	1	1	5
Tulsi[c]	1	4	3	1	1	1	5
Nardha[c]	1	7	2	1	1	1	5
Pandar Bhata	2	2	2	1	1	1	5
Kura[b]	2	6	0	1	1	1	5
Total:	39	117	32	22	22	22	

[a] WRD = Water Resource Department
[b] In these cases, presidents were unopposed. In all other cases they were elected.
[c] These WUAs each had 1 woman member elected to a position. In all others, women members were co-opted.

WUAs, duration of irrigation, number of days taken to complete first irrigation, fluctuation in rainfall and agreed area, cooperation, exclusion and technical arrangements—all these factors affect interactions among irrigators (Tables 4 and 5).

MBC is located at the middle of the main canal with 9, 19 and 8 distributaries irrigating fields of farmers in the head, middle and tail reaches, respectively. Canal irrigation in Chhattisgarh is essentially protective in nature and provided at critical crop-growth stages in paddy production. Water requirement for paddy varies according to soils, varieties and field levels (Table 6). The canal remains open during August to October and the first irrigation takes about 25 days to cover the last farmer of the command area due to field-to-field irrigation through gravitational flow. The canal feeds 140 irrigation tanks. These tanks have multiple uses such as fish culture and use by the human and animal populations of the villages located within the physical boundaries of WUAs (see also Marothia 1992). Nearly 87% of the total command area is under agreement with farmers to irrigate their fields. The remaining farmers could not be brought under the agreement because water supply to their fields could not be assured.

There are five distributaries that suffer from water scarcity (Table 4). MBC provides water to 22 WUAs covering, on average, 9 territorial committees, 8 villages, 2,171 farmers and 1,693 ha of command area (Table 7). Out of 22 WUAs, only 5% have an adequate water supply. The remaining 41% and 55% receive moderate and scarce water, respectively, to irrigate their delineated water area. As a result, there is significant variation in paddy yields across the WUAs (Table 7).

The physical boundaries of the irrigation system are well demarcated by the water users' area and therefore water distribution is assumed to be effectively coordinated within the command area under control of WUAs. Each WUA has a managing committee with elected and nominated members and one elected/co-opted women member to perform a different function related to maintenance and distribution of water (see Table 5).

Table 6. Water requirements for paddy.

(A) Water requirements for paddy according to soil type		
Crop duration	**Total water requirements (cm)**	
	Medium soil	**Heavy soil**
Short duration (HYVs[a]) up to 125 days	Below 150	120
Medium (HYV) 125–140 days	General 166	134
Long (traditional) >140 days	High >184	138

(B) Average water requirement at field level and paddy stage	
Stage	**Water requirement at field level (mm)**
Nursery preparation	275
Mulching and transplanting	275
Evaporation	646
Seepage and percolation	400
Total	1,596

[a] HYV = high-yielding varieties

Table 7. Yield variation across adequate, moderate and scarce water availability zones (WUA = water users' association).

Particulars	Amount
Percentage (%) of WUAs in each water availability category	
Adequate	
Moderate	41
Scarce	55
Average yield of paddy (kg/ha)	
Adequate	2,200
Moderate	1,920
Scarce	1,100
Paddy yield variation compared with adequate water availability zones (%) across the WUAs	
Adequate	100
Moderate	80
Scarce	50

The profile of WUAs presidents is shown in Table 8. It can be seen from the table that a sizable number of the presidents are literate and their main occupation is agriculture. The elected presidents fall evenly into the different categories of farm size. However, the majority of them are located at the tail end of the command area under the jurisdiction of WUAs. Most of the presidents belong to backward social castes and many have political affiliation with the ruling party of the State. More encouragingly, 45% of elected presidents do not belong to any political party. There is a noticeable difference in the farm income of the elected presidents.

Community attributes such as irrigators' sources of income, and presence or absence of social, economic, political, cultural and locational differences among irrigators affect the irrigators incentive to cooperate. Each of these attributes has the potential to affect collective actions and outcomes in each WUA. Every WUA has a list of eligible irrigators, and hence non-members can be effectively excluded. Every WUA has a managing committee with a few sub-committees to enforce the institutional arrangements related to boundary rules, allocation rules, input rules, penalty rules, and conflict settlement rules through collective choices. There is significant variation in income, crop varieties grown, assets, and socioeconomic and political influence among the farmers located across water zones within WUAs. Similarly, a few WUAs are politically powerful enough to influence water discharge from main canal/ distributaries/minors and also get their work plans approved without delay. The nominated members also generally remain in touch with managing committees (particularly with the president), with active WUAs having political lineage. It was noticed during the group discussions that conflict sometimes arose between and among WUAs, particularly those located in scarcity zones.

Outcomes of institutional arrangements and collective action

External and internal institutional arrangements are well defined at each level of PIM and these are capable of structuring collective choices with respect to irrigation systems and farmers located in the different zones within a command area, as defined by the first two sets of attributes in the conceptual model. Since distributary and project committees are in the process of formation, decision-making arrangements and their implementation have largely been the responsibility of WUAs. The managing committees of WUAs are supported by nominated members in financial and water management matters. Training to perform various operational and maintenance activities for rehabilitation of irrigation networks has been given to elected members by the master trainers. The master trainers (nominated members) were trained by the Water and Land Management Institute, Bhopal (Madhya Pradesh), before being nominated by the WUAs.

The effectiveness of external and internal institutional arrangements was assessed using input generated from group discussions and a series of meetings with the members of WUAs regarding transparency, upkeep of records, water management and distribution, participation of WUAs in determination of irrigated areas and collection of water tax/fees, financial resources, and general awareness (Table 9). These parameters provide some patterns of interactions among water resource users, managing committees of WUAs and the WRD. We have also assessed the working efficiency of WUAs in terms of their activities (general body and managing committee meetings, leadership, capability to take on responsibilities and lead, repairs/maintenance of irrigation systems, level of participation and dispute management, finance and accounts, horizontal and vertical link-

Table 8. Profile of water users' association presidents.

Item	Categories	Number	Percentage
Educational background	Nil	1	5
	Up to 7th class	1	5
	From 7th to 12th class	14	63
	College level	6	27
	Total	22	100
Age	Under 30 years	2	9
	30–50 years	14	63
	50–70 years	3	14
	Over 70 years	3	14
	Total	22	100
Occupation	Agriculture	17	76
	Service	1	5
	Business	3	14
	Contractor	1	5
	Total	22	100
Cultivable land under command area (hectares)	0–5	6	27
	6–10	3	14
	11–20	7	32
	Over 20	6	27
	Total	22	100
Location of farm along watercourse	Head	7	32
	Middle	10	45
	Tail	13	59
	Total	22	100
Caste	General	4	18
	OBC[a]	15	68
	SC[b]	3	14
	Total	22	100
Farm income (Rupees)	Up to 15,000	5	22
	15,000–30,000	7	32
	30,000–45,000	3	14
	45,000–60,000	2	9
	Over 60,000	5	23
	Total	22	100
Political affiliation	None	10	45
	CI[c]	12	55
	Total	22	100

[a] Other backward class
[b] Schedule caste
[c] Congress-I
Source: Water Resources Department, Government of Chhattisgarh.

ages with other organisations, water distribution and creating awareness about appropriate agriculture systems, and financial and social audit (Table 10).

Questions about collective choice rules in all the 22 WUAs were asked in the group meetings and field walks to assess the extent of awareness of institutional arrangements from members of the managing committees and other farmers. The responses of WUAs to the awareness of collective rules are presented in Table 9. In most cases, major collective decisions concerning the execution and assessment of maintenance and repairs works are made in meetings of managing committees and sub-committees that involve elected and nominated members of WUAs. General meetings for all members were held only in two WUAs, and even in those cases, only one meeting was held. Managing committee meetings were held more frequently to discuss matters related to irrigation system management. Members of the managing committees of all 22 WUAs thought that there was total transparency in the functioning of WUAs. All the WUAs have basic information about their command areas, legitimate registered members and maintain record registers. Although all the members of the managing committees of WUAs have information about the quantum of water their members should get, only 12 WUAs have a measuring device at the distribution point and only six WUAs measure the daily discharge flow of water. Field-to-field water distribution systems are prevalent in all the WUAs. In many cases, distribution is distorted. In normal years, farmers located in tail-end zones of command areas get water in 10 WUAs. In most cases, farmers have knowledge about determined irrigated area and feel that with the rehabilitation of the canal network, the determined area has slightly increased over previous years (Table 9). All the WUAs are comfortable with the prevailing water rates fixed by the apex body.

For every WUA, there is well-specified work plan for maintenance and repairs. Each WUA has to submit their work plan for approval and release of funds to the appropriate authority of WRD. Payments for maintenance and repair of the MBC and its distributaries/minors and water regulatory devices have been sanctioned and received at Rs50/ha by WUAs from the apex body. Almost all WUAs have utilised 95% of the funds allotted to them (Table 11). However, only 62% of farmers paid their irrigation fees. The farmers and WRD are in the process of learning to pay and collect water charges. However, only three WUAs could generate some income from grasses, fish and fines.

There is a well-structured formula for sharing irrigation revenue among WUAs, distributary committees and project committees (Table 12). Since distributary and project committees have not yet formed, total funds are supposed to be retained by WUAs. However, until May 2001, the irrigation fund was not released to WUAs on the ground that distributary and project committees will be constituted soon. All the WUAs claim to have complete knowledge of the PIM Act and its related provisions.

The level of water supply and the degree of rule conformance and maintenance are closely related to one another (Table 10). An adequate supply of water encourages a high degree of rule conformance and maintenance, and vice versa. Only 5% of WUAs have adequate water supply whilst the remaining 41 and 55% of WUAs have moderate and scarce water supply and information about the water distribution system. The performance of all the WUAs was poor in terms of voluntary labour contribution, efforts for water saving, social audit and fund generation. The WUAs could not establish vertical linkages with distributary and project committees due to the reasons mentioned above. The WUAs, therefore, have established links with sub-divisional officers directly or through nominated members. The flow of extension services, members' awareness about the status of financial audits, and the level of participation of the members in all the WUAs are at a low level of performance. Moderate performance was reported for activities related to productive/successful managing committee meetings and leadership capability, horizontal linkages with other WUAs, information and communication linkages, and efforts for land development. The performance of WUAs in terms of removal of silt and weeds, repairs/maintenance of structure, dispute management, and discussions with competent authorities was mixed (Table 10).

Table 9. Responses of water users' associations (WUAs) reflecting awareness of collective choice rules.

Particulars	% and (no.) of WUAs agreeing to positive outcome	
Assessment of function of WUAs by member of managing committee		
No. of general body meetings held	9	(2)
No. of meetings of managing committee held	100	(22)
Has general body approved repairs/maintenance work?	–	
Are the sub-committees consulted?	100	(22)
Execution of work done by local contractor, member/president, TMC and farmers	100	(22)
Assessment of quality of work done from farmers, TMC, member/president, authorised officer	100	(22)
Upkeep of repairs and maintenance records		
Do you have a map of the irrigated area available to the WUA?	100	(22)
Do you have list of the farmers who are eligible for voting?	100	(22)
Do you have list of members who are not eligible for voting?	100	(22)
Do you maintain a records register?	95	(21)
Water management and distribution		
Do you know how much water you should get from your delineated area?	100	(22)
Do you measure the daily discharge flow of water?	27	(6)
Is there any system for distribution of water at minor canals, heads and regulator sluice gates?	–	
Are there any water-measuring structures at the distribution points of the distributries/minors?[a]	55	(12)
Is water provided in all tail-end areas?[b]	45	(10)
Determination of irrigated area and collection of water tax/fees		
Are you familiar with determination of irrigated area?	41	(9)
Ha there been an increase in determined area compared to previous few years?	100	(22)
Is the water tax as per your assessment?	100	(22)
Do farmers have knowledge about determined area?	100	(22)
Do you assist in collection of water tax?	27	(6)
Financial resources		
Do you receive the payment for maintenance/repairs work?	100	(22)
Do you receive income from grass, fish, nenalties?	14	(3)
Have you collected the water fees?	–	
What is the planning to start the collection of fees (current and coming year)	–	
Do you have knowledge of related provisions of the Act?		
Returning of elected members	100	(22)
Received/collection development charges from all farmers	100	(22)
Assessment of financial account	100	(22)
Assessment of social account	100	(22)
Filling up of vacant posts of members (depending on the season)	100	(22)
Action against member for damaging the system/distributaries of water	100	(22)
Water distribution to agreement area	100	(22)

[a] All distributaries have a gauge point, but most minors do not.

[b] In drought years.

Table 10. Performance of water users' associations.

Particulars	Level of performance (%)[a]			
	High	Medium	Low	Poor
Activities				
Productive meetings	–	100 (22)	–	–
Leadership capability	–	100 (22)	–	–
Repairs/maintenance of system				
Removal of silt and weeds	41 (9)	54 (12)	5 (1)	–
Repairs/maintenance of structure	41(9)	54 (12)	5 (1)	–
Protection of structure	–	100 (22)	–	–
Voluntary labour contribution	–	–	–	100 (22)
Level of participation				
Participation	–	–	100 (22)	–
Dispute management	–	23 (5)	54 (12)	23 (5)
Financial management				
Fund generation	–	–	5 (1)	95 (21)
Accounting	–	18 (4)	41 (9)	41 (9)
Organisational linkages				
Horizontal linkages with other WUAs	–	100 (22)	–	–
Vertical linkages	–	–	–	100 (22)
Information and communication	–	100 (22)	–	–
Discussion with competent authority	9 (2)	68 (15)	23 (5)	–
Water management				
Adequate water supply	5(1)	41(9)	55(12)	–
Information about water distribution pattern	100 (22)	–	–	–
Efforts to save water	–	–	–	100 (22)
Agriculture system/cropping system				
Effective flow of extension services to WUAs	–	–	100 (22)	–
Efforts in land development by WUAs	–	100 (22)	–	–
Members awareness about status				
Financial audit	–	9 (2)	91 (20)	–
Social audit	–	–	–	100 (22)

[a] Figures in brackets indicate number of WUAs. Level of performance = 3 (high), 2 (medium), 1 (low), 0 (poor).

Table 11. Performance of water users' associations (WUAs) in maintenance and reported against financial assistance granted.

Name of WUA	Command area (ha)	Total no. of farmers	Financial assistance received (Rs)	% of fund utilised for maintenance and operations	Number of farmers paying irrigation fees (%)	Percentage of farmers not paying irrigation fees (%)
Belar	2,272	2,417	113,600	95	1,571	35
Bhrenga	1,500	1,115	75,000	95	669	40
Sharkhi	1,924	2,632	96,200	95	1,711	35
Khorpa	1,975	1,737	98,750	95	1,042	40
Parsada	1,224	1,238	61,200	95	743	40
Tekari	1,441	1,684	72,050	95	1,095	35
Shishanpari	1,967	1,743	98,350	95	1,133	35
Boryakala	2,081	2,320	104,050	95	1,508	35
Mana	1,980	2,606	99,000	95	1,694	35
Dunda	1,786	2,225	89,300	95	1,335	40
Urla	1,946	1,713	97,300	95	1,028	40
Kurud	1,701	2,263	85,050	95	1,358	40
Hirapur	1,008	2,513	50,400	95	1,508	40
Dharsiwa	1,506	2,263	75,300	95	1,358	40
Mohdi	1,417	2,252	70,850	95	1,464	35
Sivni	1,640	3,133	82,000	95	1,880	40
Mandhar	1,919	2,306	95,950	95	1,499	35
Semariya	1,766	2,528	88,300	95	1,643	35
Tulsi	1,706	2,715	85,300	95	1,629	40
Nardha	1,866	2,499	93,300	95	1,499	40
Pandar Bhata	1,554	1,325	77,700	95	795	40
Kura	1,056	2,530	52,800	95	1,518	40
Total:	37,235	47,757	1,861,750	95	29,679	38

Table 12. Percentage distribution of share of irrigation revenue.

Irrigation project	Water users' association	Distributary Committee	Project Committee	Village Panchayat
Major	50	20	20	10
Medium	60	30	–	10
Minor	90	–	–	10

Conclusions and Policy Implications

A few State governments, practitioners and scholars involved in irrigation management in India have recently begun to realise the limitation of relying primarily on government bureaucracies to solve development and collective action problems and design complex institutional arrangements linking State agencies with local water users. The failure of many large, medium and small irrigation projects to deliver projected benefits to farmers beyond pipe outlets clearly indicates the limitation of State control over canal irrigation water. Thus, some scholars from political science, agricultural and natural resource economics, anthropology, legislative science, and environmental engineering have turned their attention to the importance of a PIMS to achieve self-governing irrigation systems within a framework of distributed governance in solving collective action problems. Recently, government bureaucracies in India have undertaken fruitful initiatives in reforming irrigation and other natural resource management sectors. One example of this is the introduction of PIM introduced in Madhya Pradesh and Chhattisgarh States.

The analysis presented in this paper indicates that the PIMS is in the process of transformation from State control to a self-governing system. It is important to realise that the PIM model was only introduced two years ago. The successful adoption of the PIMS requires a complete change in mindset, and the officers of WRD, members of the managing committees of WUAs and farmers are still in a learning process. The preliminary results of the present study indicate that, despite the maintenance and repairs made to the main canal, distributaries and field channels beyond pipe outlets by all WUAs, a large number of WUAs and farmers located in different zones along water courses suffered from water scarcity at the critical crop-growth stages. In fact, the canal network was in a very bad shape even before transferring the irrigation management to the WUAs. Although the external and internal institutional arrangements are well defined at each level of PIMS, and have capability of structuring collective choices with respect to the irrigation system and farmers within a command area, the enforcement of these arrangements and outcomes thereof are at best satisfactory in terms of awareness and performance. In order to ensure adequate and equitable water supply and minimal cleavages (social and economic differences among farmers and WUAs), effective implementation of institutional arrangements with dynamic WUAs is needed. This is important because many WUAs are socioeconomically/politically very powerful and often influence repair, maintenance and water distribution. In the process, the WUAs without political lineage get lower preference in seeking funds and approval of their proposals for repair and maintenance. In WUAs with adequate water availability, there is cut-throat competition among the members to contest election to management committees and sub-committees. However, it is difficult to find candidates for president and members in the water scarcity zone for managing committees. The nominated members are overburdened with departmental work and it is difficult for them to participate actively in WUAs. Also, to strengthen WUAs, the formation of distributary and project committees is urgently required. As per the provision in the Act, the share of WUAs in irrigation revenue may be transferred to enhance the financial capability of WUAs. The responsibility for collecting irrigation fees may also be entrusted to WUAs for greater involvement in water management. In many cases, managing committees of WUAs face serious problems in maintaining records. In such situations, the managing committees are largely depending on sub-engineers (coordinators of the managing committees) for maintaining the records and getting approval for maintenance and repairs works from executive engineers of WRD. Periodic training for official members (superintendent and executive engineers), and nominated and elected members of the committee is required to educate them about the importance of institutional arrangements to achieve self-governance in canal irrigation systems. The sustainability of PIMS largely depends on political and bureaucratic will to share power with farmers and create an apolitical environment for the smooth functioning of WUAs.

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Appendix 1: Further Details on the Implementation of Participatory Irrigation Management in Madhya Pradesh and Chhattisgarh

Because of inadequate maintenance over the years, many canal systems in both States have deteriorated, adversely affecting their capability to deliver service as per design. Some systems are old and are in need of rehabilitation, improvement and modernisation, taking into account the changes in cropping pattern and agricultural practices. After the creation of water users' associations (WUAs) in pursuance of the legislation on farmers' participation in irrigation management, the management of irrigation systems was transferred to WUAs. The State Department of Water Resources Development (WRD) realised that the process of transfer of canal system management to WUAs needed to coincide with restoration of deteriorated canal systems to a satisfactory operational capability in order to convey the designed discharge in all distributaries, minors and distribution systems in a timely and equitable manner. Improving the operational capability level of the canals was considered essential for subsequent orderly and smooth canal operation by the WUAs.

By August 1999, the WRD, with the local knowledge of farmers, delineated various command areas of the irrigation system on an hydraulic basis at all levels, i.e. minor, medium and major projects, which were administratively viable to form viable areas for each WUA. These WUAs were notified by the relevant District Collector. Elections of WUAs were held by December 1999 and the complete canal system was handed over to WUAs for operation and maintenance immediately thereafter, to ensure that irrigation for Kharif-2000 was done by the WUAs. The District Collectors were the election authorities. The District Collector made arrangements for election of presidents and members of the managing committees of the WUAs by direct elections.

The participatory irrigation management system (PIMS) involves revolutionary legislation promoting a total change in the management of irrigation systems through farmers' organisations. Farmers' organisation (FOs) include WUAs at the primary level, distributary committees (DCs) at the distributary level and project committees (PCs) at the project level (Figure A1). The institutional structure of the FO was as follows: (i) minor irrigation schemes: single tier, i.e. only WUAs (up to 2,000 ha), (ii) medium schemes: two tier, i.e. WUAs and PCs (2,001–10,000 ha), (iii) major schemes: three tier, i.e. WUAs, DCs and PCs (10,001 ha and over).

In all the above categories, the water users' area for an individual WUA is restricted to maximum of 2,000 ha. The area of a WUA is sub-divided into territorial constituencies with a minimum of 4 and a maximum of 10, depending upon the size of the water users' area. The delineation of water users' area and its sub-division (territorial constituencies) is based on hydraulic parameters and must be hydraulically viable. Every WUA is called by its local, distinct name.

The process of formulating the Act involved farmers' workshops and seminars. The Act has the following unique features: *(a)* transfer of power to manage State assets; *(b)* creation of new, autonomous institutions as legal entities; *(c)* areas defined on a hydraulic basis; *(d)* equity achieved within the structure of the WUA by introducing the concept of territorial constituencies; *(e)* all landholders in possession of land in an irrigation system—members with voting rights; *(f)* one member one vote; *(g)* elections by secret ballot; *(h)* functional and administrative autonomy; *(i)* freedom to raise resources; *(j)* resolution of disputes and compounding of offences; *(k)* simplified procedures for taking up of works; *(l)* five-year tenure (WRD) as competent authority is made fully accountable to the farmers' organisation; *(m)* right to recall an elected member after one year; and *(n)* social audit and annual accounts audit.

The Act provides procedures and guidelines on accounting, water budgeting, election procedures and other administrative matters that are to be done by WRD. Accordingly, in Madhya Pradesh, including Chhattisgarh, a total of 2,433 WUAs have been constituted. In Chhattisgarh, 942 WUAs have been constituted.

Organisational structure of PIM

The organisational structure of PIM is depicted in Figure A1. For effective implementation of PIM at WUAs' distributary, project and apex levels, by-laws/institutional arrangements have already been prepared for each level and made effective since June 2000. The by-laws clearly spell out the working zones, objectives, functions, responsibilities, organi-

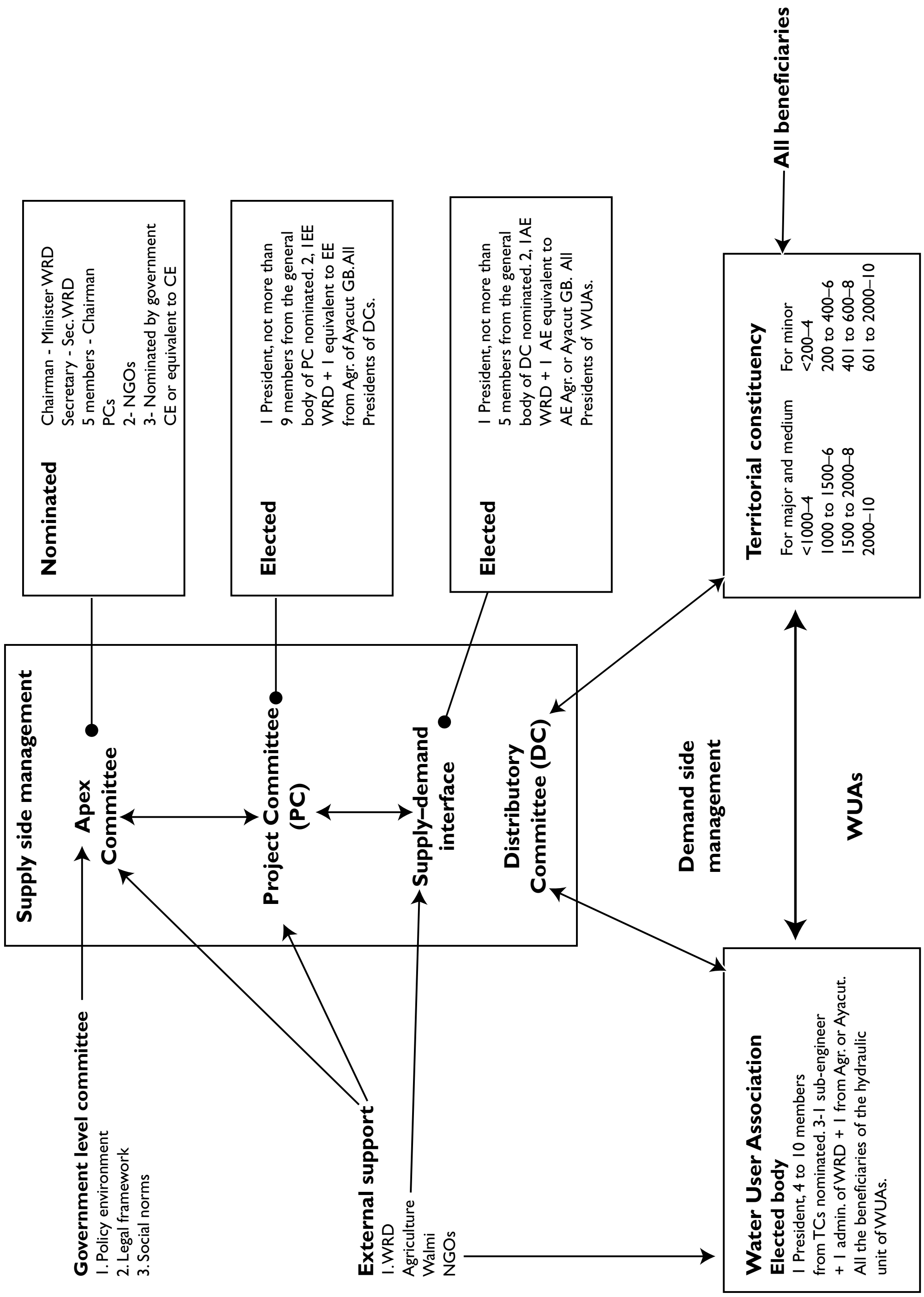

Figure A1. Participatory irrigation management: institutional structure from water users' associations (WUAs) to Apex Committees.

sation administrative and financial set-up, and the duties and rights of the members of the governing bodies operating at WUA, distributary, project and apex levels.

At the WUA level. Every command area in the irrigation system, on a hydraulic basis, is delineated on a hydraulic basis as water users' area for each WUA. The water users' area is then divided into territorial constituencies that are not generally less than four but not more than ten, according to the size of command area under the control of the WUAs. The general body of the WUAs consists of all water users in a water users' area, three ex-officio members, one of Amin Cadre and one of Sub-Engineer Cadre from WRD—who act as coordinators between the government departments and the farmers' association—and the third from the Agriculture Department of the Ayacut Department who acts as an advisor (Figure A1). A farmer is eligible to become a member of more than one territorial constituency of a WUA, but he is entitled to be a member of only one territorial constituency through which he/she can exercise his option. All members of WUAs have the right to vote. For every WUA, there is a managing committee that consists of a president and one member from each of the territorial constituencies for the water users' area. The president and members of the managing committee are elected by direct election by method of secret ballot for a period of five years, if not recalled earlier, from the date of the first meeting. The District Collector conducts the elections. If the managing committee of the WUA does not have a woman member, the managing committee co-opts a woman as a member who would ordinarily be resident in the farmers' organisation area. The managing committee exercises the powers and performs the functions of the WUA.

At the distributary level. Every command area of irrigation system is delineated, comprising two or more WUAs, as a distributary area. The distributary committee is responsible for managing a delineated distributary area. The distributary committee is also known by its distinct name for every distributary area. The presidents of the WUAs in the distributary area constitute the general body of the distributary committee, including two nominated official members. One of them is an Assistant Engineer of WRD, who works as a coordinator between the various departments, WUAs and distributary committee, and the second member acts as an advisor who is from the Agriculture or Ayacut Department (Figure A1). For every distributary committee, there is a managing committee. The president and members of the managing committee, which should not number more than five from amongst the members of the general body of the distributary committee, are elected by secret ballot. The elections are conducted by the District Collector.

At the project level. A project committee called by its distinct name is responsible for managing the project area delineated in a command area or part thereof. All the presidents of the distributary committee in the project area (so long as they hold such office) constitute the general body for the project committee. The project committee has two nominated members, one of whom acts as a coordinator (an Executive Engineer of WRD) between various departments and farmers' associations and a second member who acts as advisor (from the Agriculture or Ayacut Department). The nominated members have no right to vote (Figure A1). As in the case of WUAs and distributary committees, for every project committee there is also a managing committee. The election of a chairperson and managing committee, consisting of not more than nine members from amongst the members of the general body of the project committee, is conducted by secret ballot by the collector. If the managing committee of the project committee does not have a woman member, the managing committee co-opts a woman as a member who shall ordinarily be a resident of the farmers' organisation area. The term of office of the chairperson and the members of the managing committee is five years from the date of the first meeting. The managing committee exercises the powers and performs the functions of project committee.

At the State level. The State Government has constituted an apex committee for overall supervision of the PIMS. The committee consists of the Minister of Water Resources as chairperson and five people from amongst the chairpersons of the project committees. Two people from non-government organisations and three officers not below the rank of Chief Engineer or equivalent from the WRD, or the Agriculture or Ayacut Department of the State Government are also on the committee. The number of members may be increased by such a number as may be considered necessary by the State Government (Figure A1). The committee exercises such powers and functions as may be necessary to lay down the policies for implementation of the provisions of this Act.

Functions and responsibilities of WUAs and distributary and project committees

The functions and responsibilities at each organisational level are well defined in the PIM Act. The basic structure of the organisation at each level is interrelated and responsibilities and rights are distributed among and within the WRD, Agricultural Department (State wings), and managing committees of WUAs, DCs and PCs (see Table 1 for detailed structure of functions and responsibilities of WUAs, DCs and PCs). Major institutional changes have been introduced after PIM at each level of management (see Table 1). The distributary and project committees have not been formed so far. The WUAs are performing their functions with the support of sub-engineers of Water Resources Department and Agriculture Extension Officers of the Agriculture Department. These are the nominated members in WUAs. Currently, the water irrigation fees are collected by the Deputy Revenue Collector who is under the direct control of WRD. The distribution of shares of irrigation revenue collected from the farmers is well specified and given in Table 12. The WUAs are responsible for preparing work plans within a given time frame and submitting them to WRD for approval. The schedule of work plans and structure of limits for approval of financial assistance are given in Table A1.

Resources of farmers' organisations

The farmers' organisation generates funds from: (a) grants and commissions received from the State Government as a share of water tax collected in the area of operation of the farmers organisation; (b) such other funds as may be granted by the State Government and Central Government for the development of the area of operation; (c) resources raised from any financing agency for undertaking any economic development activities in the area of operation; (d) income from the property assets attached to the irrigation system; (e) fees collected by the farmers' organisation for their services rendered in better management of the irrigation system; and (f) amounts received from any other sources.

Table A1. Schedule for work plan and structure of approval of funding for repairs and maintenance.

A. Schedule for work plan	
Subject	**Per Year**
1. Planning of maintenance repairs preparation	30 Nov.
2. Estimated cost	31 Dec.
3. Budget head finalisation	15 Jan.
4. General maintenance work	28 Feb.
5. Finalisation of work through tender	31 March after closing of canals
6. Completion of general work other than minor work which can be done during completion of work	31 May before delivery of water
7. Preparation of work report	31 July
B. Structure of approval of funding for repairs/maintenance	
Authority	**Approved financial limits**
Approval repairs/maintenance Executive engineering	Whole power
Special repairs/maintenance	
Executive Engineer	Rs. 5000/–
Superintendent Engineer	Rs. 50,000/–
Chief Engineer	Rs. 5,00,000/–

Water rates

WRD provides water to a large number of farmers for irrigation purposes, to municipalities for human and domestic uses, to the State Electricity Board for power generation, and to industry for industrial uses. The Government of Madhya Pradesh revised the water rates from 15th June 1999 for supply of water from all tanks, canals etc. and these rates are also effective in Madhya Pradesh and Chhattisgarh States for the crops specified in Table A2. In Chhattisgarh, canal water is provided at the critical crop-growth stages in paddy production. Generally, three irrigations are given in normal years, but during drought years water is not always available for irrigation. There is no provision to give water in the Rabi season. In some areas, summer paddy is being grown but the water requirements are much higher than the Kharif paddy. The Water Resources and Agricultural Departments have not been in favour of providing water for summer cultivation of paddy.

Similarly, the water rate for industrial use from government sources is R1.0/m^3. In addition, the government has also decided to levy the revenue for water from irrigation sources developed by the private user at 30 paise/m^3. Further, the water rate shall also be collected for generating hydropower, which shall be 2 paise and 10 paise per kilowatt from the government-owned dams and privately-owned dams, respectively.

Table A2. Schedule of water rates of water supply from irrigation works for agricultural purposes (flow and lift irrigation).

Name of crops	Water rates (Rs/ha)
Rice—Kharif	202.5
Rice—Rabi	500.5
Wheat	
Maximum three waterings including Palewa	202.5
For each extra watering	62.5
Banana, betel, garden crops, rubber plants, sugarcane	750.0
Green fodder crops, groundnut (Kharif), Jowar, Moong (Kharif), soybean (Kharif), Til, Tur (Kharif), Urd	125.0
Coriander, Gra, groundnut (Rabi), Moong (Rabi), mustard, safflower, soybean (Rabi), Tur (Rabi)	250.0
Cotton—ordinary	187.5
Cotton—hybrid	375.0
Barley, Brinjal, carrot, cauliflower, chilli, cucumber, Dalocasia Feb-Greek, ginger, garlic, Gwarphali, ladies finger, mulberry, pea, poppy seed, pumpkin, potato, radish spinach, tobacco, tomato, tumeric, watermelon, green vegetables.	500.0
Barseem grass (fodder crop)	375.0
Water for land preparation (Palewa)	100.0

Investment and Institutions for Water Management in India's Agriculture: Profile and Behaviour

Vasant P. Gandhi and N.V. Namboodiri*

'While it is essential to understand the physical side of irrigation systems, much of the emphasis in design of new or rehabilitated systems will be on the institutional side.' Elinor Ostrom (1992)

Abstract

This paper profiles the development and status of water resource management in India with a focus on institutional aspects and investment behaviour. The crisis of water management is becoming increasingly serious in India as development accelerates. The management of the distribution of water across the vast areas of the country, and amongst millions of users, in a way that is sustainable, is becoming a major problem. The technical and economic solutions are typically known and often simple, but the institutional management in the political economy is becoming very difficult and posing a serious challenge. According to World Water Vision 2000 agriculture is the largest user of water resources, and will continue to be up to 2025. But the countries vary greatly in the importance of irrigation to their agriculture. In India, less than 30% of the area receives high/assured rainfall, and more than 70% of the rain is received only in the 4-month monsoon period. Thus, irrigation assumes great importance for intensive farming, and has received considerable priority in agricultural development. Currently about 40% of the cropped area is irrigated through both surface and ground water sources, but there are numerous problems and the potential is much greater. Most of the irrigated area is under food grains, and therefore, water management has large implications for food security.

Analysis of the behaviour of irrigation investment indicates that government capital stock, private capital stock, price of energy, rural savings and credit are major determinants. However, pricing and investment issues are small in importance relative to the institutional problems that mark most of the failures of irrigation development in the country. Research indicates that characteristics of water, such as its lumpiness, fugitiveness, externalities, transaction costs and information deficiencies lead to extensive market failures in water resource management. This makes institutional control essential, but designing institutions to deal with the peculiarities of water in a way that leads to sensible incentives and efficient resource use is a very challenging task. The paper indicates that there is critical need in India to search for new institutional arrangements in water resource management, which lead to its use reflecting its real scarcity, achieves equitable distribution, generates necessary investment, and avoid ill effects on the soil and the environment.

THE crisis of water management is becoming increasingly serious in India as development accelerates. Local scarcities are becoming common and frequent and quality is declining as well. The management of the distribution of water across the vast areas of the country, and amongst millions of users, in a way that is sustainable, is becoming a major problem. Irrigation is now crucial to agriculture for production as well as livelihoods. There is a crisis in the management of surface water because of huge investment requirements, project implementation problems, the need and expenses for maintenance, institutional difficulties in distribution, and environmental concerns. There is a crisis also in the management of groundwater because of excessive exploitation and inadequate recharge of the watertable in many areas. The technical and economic solutions to these are typically known and often

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simple, but their institutional management in the political economy is becoming very difficult and posing a serious challenge. This paper provides an overview of the development and investment in water resource management in India for agriculture, the behaviour of the growth in irrigation, an outline of the present situation, and the institutional problems and issues that are becoming of great importance today and for the future.

World Water Situation

> There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water badly—such that billions of people and the environment suffer. (World Water Vision 2000)

Outlining the world situation, Table 1 indicates that the withdrawal of water for agriculture more than doubled from 500 cubic kilometres (km^3) in 1900 to 1,100 km^3 in 1950, and it once again more than doubled to 2,500 km^3 in 1995. However, the industrial use increased at a more rapid rate—from 40 km^3 in 1900 to 750 km^3 in 1995, and the use by municipalities increased at an even more rapid rate—from 20 km^3 in 1900 to 350 km^3 in 1995. But of the total withdrawal of 3,800 km^3 in 1995, the largest user remains agriculture at 2,500 km^3 (World Water Vision 2000).

The World Water Vision projects that in the future (see Table 2), from 1995 and 2025, the withdrawal for agriculture will increase by only 6% to reach 2,650 km^3, and the withdrawal for industry will increase by 7% to reach 800 km^3. These projections are based on significant improvement in the efficiency of use of water in both agriculture and industry. However, the use by municipalities is expected to go up by 43% to reach 500 km^3 by the year 2025. Of the total withdrawal of 4,200 km^3 in the year 2025, agriculture will still remain the biggest user at 2,650 km^3.

Table 1. Global water use in the 20th century.

Use	Amount (km^3)		
	1900	**1950**	**1995**
Agriculture			
Withdrawal	500	1,100	2,500
Consumption	300	700	1,750
Industry			
Withdrawal	40	200	750
Consumption	5	20	80
Municipalities			
Withdrawal	20	90	350
Consumption	5	15	50
Reservoirs (evaporation)	0	10	200
Total			
Withdrawal	600	1,400	3,800
Consumption	300	750	2,100

Note: All numbers are rounded. Source: World Water Vision (2000).

Table 2. Renewable water use in the World Water Vision.

Use	Amount (km^3)		Increase 1995–2025 (%)	Notes
	1995	**2025**		
Agriculture				
Withdrawal	2,500	2,650	6	Food production increases 40%, but much higher water productivity limits increase in harvested irrigated area to 20% and increase in net irrigated area to 5–10%
Consumption	1,750	1,900	9	
Industry				
Withdrawal	750	800	7	Major increase in developing countries is partly offset by major reduction in developed countries
Consumption	80	100	25	

Note: All numbers are rounded. Source: World Water Vision (2000).

Table 2. (cont'd) Renewable water use in the World Water Vision.

Use	Amount (km^3)		Increase 1995–2025 (%)	Notes
	1995	2025		
Municipalities				
Withdrawal	350	500	43	Major increase and universal access in developing countries; stabilisation and decrease in developed countries
Consumption	50	100	100	
Reservoirs (evaporation)	200	220	10	
Total				
Withdrawal	3,800	4.200	10	
Consumption	2,100	2,300	10	
Groundwater over consumption	200	0		Increased recharge of aquifers makes groundwater use sustainable.

Note: All numbers are rounded. Source: World Water Vision (2000).

Table 3 indicates that the future development of water resource use will require substantial investment. The annual investment for agriculture would not change much, but that for environment and industry as well as for water supply and sanitation will need to increase from US$10–15 billion to US$75 billion, and US$30 billion to US$75 billion, respectively. Thus, of the projected future investment, 41% each will need to go for environment and industry, and water supply and sanitation. The projected total water withdrawal in 2025 of 4,200 km^3 will still be much smaller than the total available blue or renewable water resource of 40,000 km^3, and green or soil water of 60,000 km^3. Thus, the major issue is one of the economic sourcing, distribution and management of the water resource rather than shortage of total supply.

Table 3. Annual investment requirements for water sources.

Use	Billion US dollars		Share (%)	
	1995	Vision 2025	1995	Vision 2025
Agriculture	30-35	30	43–50	17
Environment and industry	10–15	75	13–21	41
Water supply and sanitation	30	75	38–43	41
Total	70–80	180	100	100

Source: World Water Vision (2000).

Table 4. Sources of water resource investment.

Source	Billion US dollars		Share (%)	
	1995	Vision 2025	1995	Vision 2025
National				
Public sector	45–50	30	58–71	25
Private sector	12-15	90	15–21	45

Source: World Water Vision (2000).

Table 4. (cont'd) Sources of water resource investment.

Source	Billion US dollars		Share (%)	
	1995	Vision 2025	1995	Vision 2025
International				
Private investors	4	48	5–6	24
Donors	9	12	12-13	6
Total	70-80	180	100	100

Source: World Water Vision (2000).

Table 4 brings out the change in the pattern of investment that is envisaged in the World Water Vision for the year 2025. It indicates that the national sources of investment will need to contribute the major share and within this the share of the private sector may rise substantially from 15–21% in 1995 to 45%. Even in the international sources, the share of private investors is envisaged to rise from 5–6% to 24%. Thus, much more of the future funding for development and management of the water resource is expected to come from private sources, and the role of the public sector and international donors is likely to diminish to about 30% of the total.

Table 5 shows the extent of irrigation coverage in selected countries across the world. Clearly the range is vast. In Egypt, 100% of the arable and permanent crop land is irrigated, compared to only 1.48% in Kenya, and 4.67% in Zimbabwe. Mexico shows a greater extent of irrigation at 22.34% as compared to the United States of America (USA) at 12.09% and Brazil at only 4.84%. India, according these statistics, shows an irrigated area of 33.59%, which is very close to that of China at 36.93%, whereas in Japan 62.82% of the area is irrigated. One of the countries with very high rates of irrigation is the Netherlands at 61.41%, while neighbouring France and Germany have only 8.38 and 3.94% irrigated land area, respectively. Thus, the importance of irrigated agriculture and the management of water resources for irrigation vary a great deal from country to country across the world.

Table 5. Irrigated area in different countries of the world in 1996.

Continent/country	% irrigated area to arable land and land under permanent crops
Egypt	100.00
Kenya	1.48
South Africa	8.03
Zimbabwe	4.67
Mexico	22.34
United States of America	12.09
Brazil	4.84
Chile	34.05
Bangladesh	42.23
China	36.93
India	33.59
Japan	62.82
Pakistan	81.39
Sri Lanka	29.15
Thailand	24.48
France	8.38
Germany	3.94
Netherlands	61.41
Spain	17.52
Australia	4.61

Source: Majumdar (2000).

Institutional History of Water Resource Development in India

Historically in India, before investments on irrigation by the state became an accepted practice, many emperors and local chiefs had devised ways of storing water in ponds and tanks (Singh 1991). Some had excavated inundation canals and 'anicuts' to draw water from rivers. Though most of these efforts were initiated by the wealthy and the influential people of the time, the responsibility for maintenance of the irrigation works and the distribution of water often remained with the farmers. Since agriculture was critical for human survival, communities developed norms and social systems for managing irrigation. Beneficiaries undertook responsibilities with regard to repairs and supervision of the system, sometimes with the help of paid staff, to seek equitable distribution of water. Some old works that still survive are typically looked after by the water users themselves with minimal support from the government (Singh 1991). The works bear testimony both to the potential of farmers for initiative and strength in sustaining organised human efforts.

During British Rule in India, the state intervened to some extent in harnessing irrigation resources on a large scale (Singh 1991). Some large barrages and reservoirs were built to store rainwater in order to sustain agriculture in years of lean rainfall. At the time of Independence, India had 22.5 million ha under irrigation, out of which 9.7 million ha was contributed by major and medium schemes. By 1985, a total potential of 68.0 million ha had been created—30.6 million ha from the major and medium projects and 37.4 million ha from minor irrigation projects. The cost of construction of major irrigation projects stood at Rs20,000 per hectare in the sixth plan period and stood at Rs35,000 per hectare by the early 1990s (Singh 1991).

Unsatisfactory irrigation management—particularly the delivery and utilisation of water at the farm level—has attracted the attention of planners and administrators for a long time. The Irrigation Commission of 1972, the National Commission on Agriculture of 1976, and high-powered committees set up by the Government of India have viewed with serious concern the current state of affairs. Starting in 1973, a coordinated approach to the development of irrigated agriculture was sought for implementation through the newly-created Command Area Development (CAD) Authorities. An important objective was to upgrade the outlet command with suitable on-farm development works so as to allow for the even distribution of water over the entire irrigation command (Singh 1991). Most States created multi-departmental project organisations headed by senior officers of government to implement the CAD program.

On-farm development (OFD) which involves construction of irrigation channels and drains, and land leveling and shaping, was the single most important activity pursued by the CAD authorities (Singh 1991). But strangely enough, the farmers did not take to them with any great enthusiasm. When the futility of executing OFD works without a determined attempt to get water to each farmer's holding became evident in the early 1980s, emphasis shifted to rotational water supply (RWS) along with OFD. The farmers now responded more favourably. However, the uncertainty of water supply and the frequent non-compliance with the prescribed RWS schedule by farmers did not bring about any marked improvement in water utilisation (Singh 1991). On the whole, CAD continues to be seen as a government program imposed from the top. There were innumerable cases of farmers willfully destroying irrigation structures and measuring devises built to facilitate the orderly distribution of water. Farmers did not adopt CAD as a program meant to benefit them and worthy of support. Faced with this reality, some project administrators argued that program implementation and water utilisation could probably be improved if farmers were given the responsibility for irrigation management. Though initially not many administrators grasped the significance of farmers' participation, some took the initiative to involve them in executing OFD works and irrigation management. The outlet command was made the unit of cooperation. Farmers receiving water from an outlet point were consulted and water users' associations were formed, each association having a chairman and a management committee.

Farmers' associations for irrigation—variously called 'pipe' committees (Andhra Pradesh), Kolaba Samities (Uttar Pradesh), Pani Panchayats (Maharashtra) or just outlet committees—were organised in several States (Singh 1991). Notable success was obtained in some projects, for example in Andhra Pradesh (Sri Ramsagar Project), Maharashtra (Girna and Mula-Kukadi Projects), Gujarat (Mahi Kadana Projects) and Rajasthan (Chambhal and Indira Nahar Pariyojana). A common experience, however, was that farmers' involvement in water management could not be sustained after construction works had been completed and a system of water distribution introduced. Many difficulties came up once the officials responsible for program implementation had been posted out to new areas. Maintenance was neglected and, at places, willful damage to structures was done. There was marked deterioration in the irrigation infrastructure and the water distribution system. Disciplined use of water received a setback. The benefits that had initially resulted from farmers' participation were gradually lost. Most irrigation committees became defunct. It became obvious that the associations had been totally dependent on agency (government) support for survival. They had not acquired any self-sufficiency or autonomy as self-managing organisations (Singh 1991). The local leadership and the existing social institutions were not able to sustain the outlet-based irrigation associations.

The experience over the last decade shows that if farmers actively participate in irrigation management there is marked improvement in water utilisation. Uphoff (1986) has highlighted some of the important benefits drawing upon international studies. There was an increase in the area under irrigation and also in the number of farmers who gained access to irrigation. In Pochapad, the irrigated area increased from 25 to 30% after Warabandi and the formation of pipe committees. Similar findings have come from the Mula Command in Maharashtra and the water users' cooperatives in Gujarat. Cooperation between farmers was found to increase and, because of this, many water-related disputes were sorted out. The agency was able to supply water with great control and economy. In Mula, for example, waterlogging had perceptibly declined after the formation of Pani Panchayats (Singh 1991). Several States have modified the old irrigation Acts to accommodate group management by farmers. Some are in the process of enabling farmers to form water cooperatives and charging for water by volume as against the usual crop acre rate.

Classification of irrigation systems in India

The Indian constitution separates various subjects into those that are the responsibility of the Central Government and those that are the responsibility of the States. Water, including irrigation, is a State responsibility. For ease of administration, government irrigation management policies usually distinguish between different components of the irrigation system.

Irrigation systems in India can be classified in different ways. One classification is as follows (Brewer et al. 1999):

- **Canal systems** include the larger irrigation systems in the country—most serve commands of more than 2,000 ha. The source of water can be a storage reservoir, diversion from a river without storage, lifting from a reservoir, diversion from a river without storage, lifting from a reservoir or river, or any combination of these. The systems are so large that management of the whole system by farmers has not been seriously considered.
- **Tank systems** include those systems smaller than the canal systems. Here the source of water is a 'tank' (small reservoir), and sometimes diversion from a stream without a storage reservoir (but typically these systems have a reservoir).
- **Lift systems** include those systems smaller than canal systems that are dependent upon lifting water from rivers or other surface sources or dependent upon lifting groundwater from tubewells or from dugwells.

Another classification based on command area is:

- **Major systems—**those with commands of more than 10,000 hectares.
- **Medium systems—**those with commands of between 10,000 and 2,000.
- **Minor systems—**those with commands of less than 2,000 hectares.

This is not used uniformly. For example, Tamil Nadu classifies all systems up to 5,000 hectares in size as 'tank' systems which are treated as equivalent to 'minor' systems. Large systems, including both 'major' and 'medium' systems, are handled by one agency, while small ('minor') systems are handled by another agency or by a separate wing of the irrigation agency (Brewer et al. 1999).

Current institutional arrangements: fees and allocation systems

All surface water in India is legally under the control of the State governments. Groundwater, however, is legally treated as the private property of the person holding the overlying land. Distribution of surface water through irrigation systems has come to be seen primarily as a form of welfare. One of the goals of irrigation management of the States is equity in distribution of water, within practicable limits, to all recognised users. Most States have government agencies concerned specifically with irrigation. Most were called, until recently, Irrigation Departments. Several have changed names recently to reflect an interest in managing water resources in general. They originated in British times as engineering agencies that dealt with construction of public works in general and later became specialised for the construction, operation and maintenance of irrigation systems. Usually they are dominated by civil engineers and are powerful organisations controlling large amounts of resources (Brewer et al. 1999).

Public irrigation management organisations in India do not attempt to deliver water to each farm. They deliver water to outlets, each serving more than one farmer. Below each outlet, farmers are collectively responsible for both water distribution and maintenance of the distribution system. Outlets generally serve areas from 5–300 ha and from 5–100 farmers (Brewer et al. 1999).

States attempt to collect revenue for the services provided by the government irrigation agencies. Some States collect fees based on crops and area, others based on land classes or other bases. Agencies responsible for assessment and for collection also vary. While assessment and collection differ among the States, the revenue collected is usually insufficient to meet operation and maintenance costs, not to speak of construction costs. In addition, most States have great difficulty in actually collecting irrigation revenue. The public irrigation agencies are funded from the general treasury. Allocations are not related to collection of revenue. Over the years, allocations have grown increasingly inadequate for operations, maintenance, and improvement of the public irrigation systems. One result of inadequate finance is that maintenance of the public irrigation infrastructure has also been inadequate (Brewer et al. 1999).

Some of the institutional systems followed for the distribution of water are described below (Mitra 1992; Brewer et al. 1999):

- ***Warabandi***. The *warabandi* system is used in agency-managed canal systems in north-western India and Pakistan. The basic allocation rule is that each farmer is entitled to a fraction of the total flow available to the system proportional to his land area within the command. To achieve this, water is supposed to be delivered to farmers below each outlet by means of a strict rotation schedule in which the length of each turn in hours and minutes is proportional to the size of each farmer's holding. Irrigation fees are charged to each farmer in proportion to the area of his holding but, sometimes depend upon the crop planted.

- ***Shejpali***. The *shejpali* system is found in western India. Under *shejpali*, every farmer is required to apply for irrigation every season. The application must indicate the crops to be irrigated and the area for each crop. The irrigation agency can then choose to approve this application or not. If the application is approved, the farmer is supposed to pay fees based on the areas of crops. Once an application is sanctioned, the agency is responsible for delivering water in amounts and on a schedule to bring the crop to maturity. Farmers below each outlet are expected to take water in turns. However, there is no fixed schedule and each farmer takes as much water as he needs before passing the turn to the next farmer.

- **Land classes system**. In much of southern India, water rights are assigned to land based on its classification. Some land is classified as entitled to two rice crops per year; some other land is entitled to only one crop per year. The irrigation agency is responsible for delivering enough water on an appropriate schedule to bring the permitted crops to maturity. Below each outlet, farmers are expected to work out how they will share the water among themselves. Fees are assessed based on the water rights of the land and are collected as part of the land taxes. Where water supplies are variable, there may be a need to adjust the area(s) to which water is delivered each season. Some adjustments are made through seasonal discussions about the water availability and demand.

- **Assured irrigation area system**. Historically, some area of eastern India followed the *satta* system. Under this system, farmers had to apply for water each season but there was no need to specify crops; rice was the assumed crop. Enough water was to be delivered to each farmer to bring the crop to maturity. Everyone who submitted an application was to pay fees. If most of the command is taken as an assured irrigation area, it is assumed every farmer will take water.

Each of these approaches to irrigation management is supported by government policies, including law, though often these are not effective. *Warabandi* has legal sanction in the *Northern India Irrigation and Drainage Act of 1873*. This law, as amended, is the basic irrigation law for the States of Haryana, Punjab, Rajasthan and Uttar Pradesh. Similarly, *shejpali* has legal support in the *Bombay Irrigation Act of 1879*. An amended version of this law is the basic irrigation law for the State of Gujarat. Maharashtra has a new law—the *Maharashtra Irrigation Act of 1976*—that continues to recognise *shejpali* as the basic approach to irrigation management, although it also authorises alternatives. Similarly, the *satta* system is based on the *Bengal Irrigation Act of 1876*. This Act, as amended, remains the basic irrigation law for the States of Bihar, West Bengal and Orissa. There is no comparable law from British time for southern India (Brewer et al. 1999).

Current state of irrigation development and water users' associations

Table 6 gives the statistics on major and medium irrigation projects that have been taken up and which have been completed in independent India. It indicates that by the eighth plan (1992–97), a total of 1,637 projects have been taken up, and 1,239 projects have been completed. The number of medium irrigation projects is the largest amongst these, and in all 1,075 medium projects have been taken up and 911 have been completed. These numbers are indicative of the number of large and medium irrigation project institutions that are in existence in the country.

Table 7 gives partial statistics on the number of water users' associations in selected States in 1991–92. The statistics indicate a total of about 4,400 water users' associations, with the largest number indicated in Kerala and Andhra Pradesh. These associations are called by different names in different States, e.g. Chak Committee, Irrigation Panchayat. It is indicated in literature elsewhere that not all of these are presently functional—a large number may be defunct.

Table 8 indicates the number of irrigation cooperative societies based on a Reserve Bank of India–National Bank for Agriculture and Rural Development (RBI–NABARD) compilation (Saleth 1996). It indicates that there are a total of 6,310 irrigation cooperative societies with a membership of nearly 400,000. It is not known how many of these societies are functional.

Table 6. Major and medium irrigation projects.

Period	Projects taken up			Projects completed		
	Major	Medium	Modernisation	Major	Medium	Modernisation
Pre-plan period	74	143	–	74	143	–
Plan period (1951–92)	278	894	146	120	668	51
Eighth plan (1992–97)	14	38	50	38[a]	100[a]	45[a]
Total	366	1075	196	232	911	96

[a] Provisional. Source: India, Ministry of Water Resources (1997).

Table 7. Water users' associations (WUAs): membership and area coverage in selected States, 1991–92.

State	Number of WUAs	Year of registration	Number of members	Area covered (ha)	Common name
Andhra Pradesh	1,396	–	–	–	Pipe Committee
Assam	2	–	–	–	Chak Committee
Bihar	–	–	630	224	Outlet Committee
Gujarat	43	1979–89	6,555	24,382	Irrigation Co-op. Society
Haryana	151	–	115	–	Farmers' Association

Source: Saleth (1996).

Table 7. (cont'd) Water users' associations (WUAs): membership and area coverage in selected States, 1991–92.

State	Number of WUAs	Year of registration	Number of members	Area covered (ha)	Common name
Himachal Pradesh	1	–	409	380	Water Users' Association
Karnataka	10	–	379	456	Water Users' Association
Kerala	2,031	1988–91	–	75,109	Beneficiary Farmers' Assn
Madhya Pradesh	736	–	–	183,000	Irrigation Panchayat
Maharashtra	4	1989–90	926	1,450	Water Management/Co–op. Society
Tamil Nadu	26	1988–92	15,863	16,543	Channel Council/Irrigation Farmers' Association

Source: Saleth (1996).

Table 8. Registered irrigation cooperatives.

State	Number of societies	Membership
Andhra Pradesh	370	26,076
Bihar	671	7,323
Gujarat	882	29,281
Haryana	7	112
Himachal Pradesh	41	2,907
Karnataka	466	27,454
Kerala	16	3,666
Madhya Pradesh	80	2,860
Maharashtra	3,081	268,906
Orissa	108	4,930
Punjab	61	973
Rajasthan	30	639
Tamil Nadu	37	7,341
Uttar Pradesh	453	16,862
Dadra Nagar Haveli	1	13
Pondicherry	6	214
Total	6,310	399,557

Source: Selath (1996), Reserve Bank of India–National Bank for Agriculture and Rural Development (RBI-NABARD) Compilation of Cooperative Societies in India.

Water Resource Management in India: Development and Trends

Water resource management is of very great importance for Indian agriculture because of growing food demand and because 60–70% of the population is dependent directly or indirectly on agriculture for their employment and livelihood. Table 9 indicates that the distribution of rainfall across the country is highly uneven. Only 8% of the area receives very high/assured rainfall, and another 20% receives high rainfall. The rest of country (72%) is in the low, dry or medium rainfall range. Table 10 further indicates that even over a year, the rainfall is highly concentrated—73.7% of rainfall is received in the southwest monsoon period of June–September. Thus, agriculture during the rest of the year is largely dependent on artificial methods of providing water.

Figure 1 indicates that out of the annual precipitation of 400 million hectare metres (Mha-m), 215 Mha-m enter into the soil and 115 Mha-m enter surface flow. Out of the surface water flow of 180 Mha-m, only 15 Mha-m are captured in reservoir and tank storage structures, and 165 Mha-m flow into rivers and streams. Only 25 Mha-m are finally used through surface irrigation. This constitutes a mere 6% of the total water available through annual precipitation and outside country flows. Figure 1 also indicates that out of the 215 Mha-m infiltrating into the soil, only 13 Mha-m is utilised for ground water irrigation and other uses. This constitutes again a mere 6% of the annual precipitation infiltrating into the soil.

Table 11 shows that the government has been making large investments in the development of irrigation. The sixth five-year plan (1980–85) and the eighth five-year plan (1992–97) show among the highest investment in irrigation in nominal terms. However, the percentage share of plan expenditure going to irrigation was the highest at 22.55% in the pre-plan period (up to 1951) and subsequently declined to 5.49% in the 1993–94 annual plan.

Table 12 shows that the total capital expenditure of both Central and State governments on irrigation reached Rs9772 crores (crore = 10 million) by 1999–2000, and has risen substantially in the last 10 years, but in nominal terms. Nearly 80% of this expenditure is put into major and medium irrigation schemes and 13% into minor irrigation projects. Thus the bulk of the expenditure is in larger irrigation projects.

Table 9. Distribution of area according to annual rainfall.

Rainfall classification	Amount of rainfall (mm)	Percentage area receiving rainfall
Low/dry	Less than 750	30
Medium	750–1,150	42
High	1,150–2,000	20
Very high/assured	More than 2,000	8
Total		100

Source: FAI (1998).

Table 10. Distribution of annual rainfall in India according to the season.

Rainfall	Duration	Approx. percentage of annual rainfall
Pre-monsoon	March–May	10.4
Southwest monsoon	June–September	73.7
Post-monsoon	October–December	13.3
Winter or northeast monsoon	January–February	2.6
Total	Annual	100.0

Source: FAI (1998), based on report from India, Meteorological Department, Pune.

Table 11. Plan-wise financial expenditure in different segments of irrigation (Rs billion).

Plan period	Major and medium irrigation	Minor irrigation		Command area development	Total	Share of irrigation in total plan expenditure (%)
		State	Institutional			
Pre-plan (up to 1951)	3.76	0.66	*	–	4.42	22.55
First plan (1951–56)	3.80	1.42	0.19	–	5.42	11.59
Second plan (1956–61)	5.76	3.28	1.15	–	10.19	11.88
Third plan (1961–66)	4.30	3.26	2.35	–	9.91	14.95
Annual plans (1966–69)	12.42	5.12	6.61	–	24.16	15.31
Fourth plan (1969–74)	25.16	6.31	7.79	1.48	40.73	14.13
Fifth plan (1974–78)	20.79	5.02	4.80	2.15	32.76	14.28
Annual plans (1978–80)	73.69	19.79	14.38	7.43	115.29	10.55
Sixth plan (1980–85)	111.07	31.18	30.61	14.48	187.34	8.56
Seventh plan (1985–90)	26.35	8.36	6.76	3.09	44.56	7.64
Annual plans (1990–92)	28.24	8.44	6.74	2.83	46.25	7.14
Eighth plan (1992–97)[a]	224.15	59.77	**	25.103	309.02	7.12
Annual plan (1992–93)[b]	28.06	9.62	8.12	3.42	49.22	6.38
Annual plan (1993–94)[a]	38.41	12.16	**	4.44	55.01	5.49

[a] Outlay; [b] Anticipated
Note: * = negligible; ** = not available; Source: Saleth (1996).

Table 12. Capital expenditure of the Central and State governments on irrigation (Rs million).

Years	Major and medium projects	Minor projects	Others	Total
1989–90	25,861	5,196	8,523	39,580
1990–91	29,166	4,803	8,261	42,230
1991–92	30,384	4,896	7,109	42,389
1992–93	29,779	9,915	5,884	45,578
1993–94	39,594	6,427	4,782	50,803
1994–95	47,719	7,382	11,109	66,210
1995–96	54,586	7,541	14,331	76,458
1996–97	54,934	9,038	6,312	70,284
1997–98	69,386	9,107	5,708	84,201
1998–99	70,899	12,229	7,874	91,002
1999–2000	76,796	12,458	8,462	97,716

Source: India, Ministry of Finance (1996, 1998).

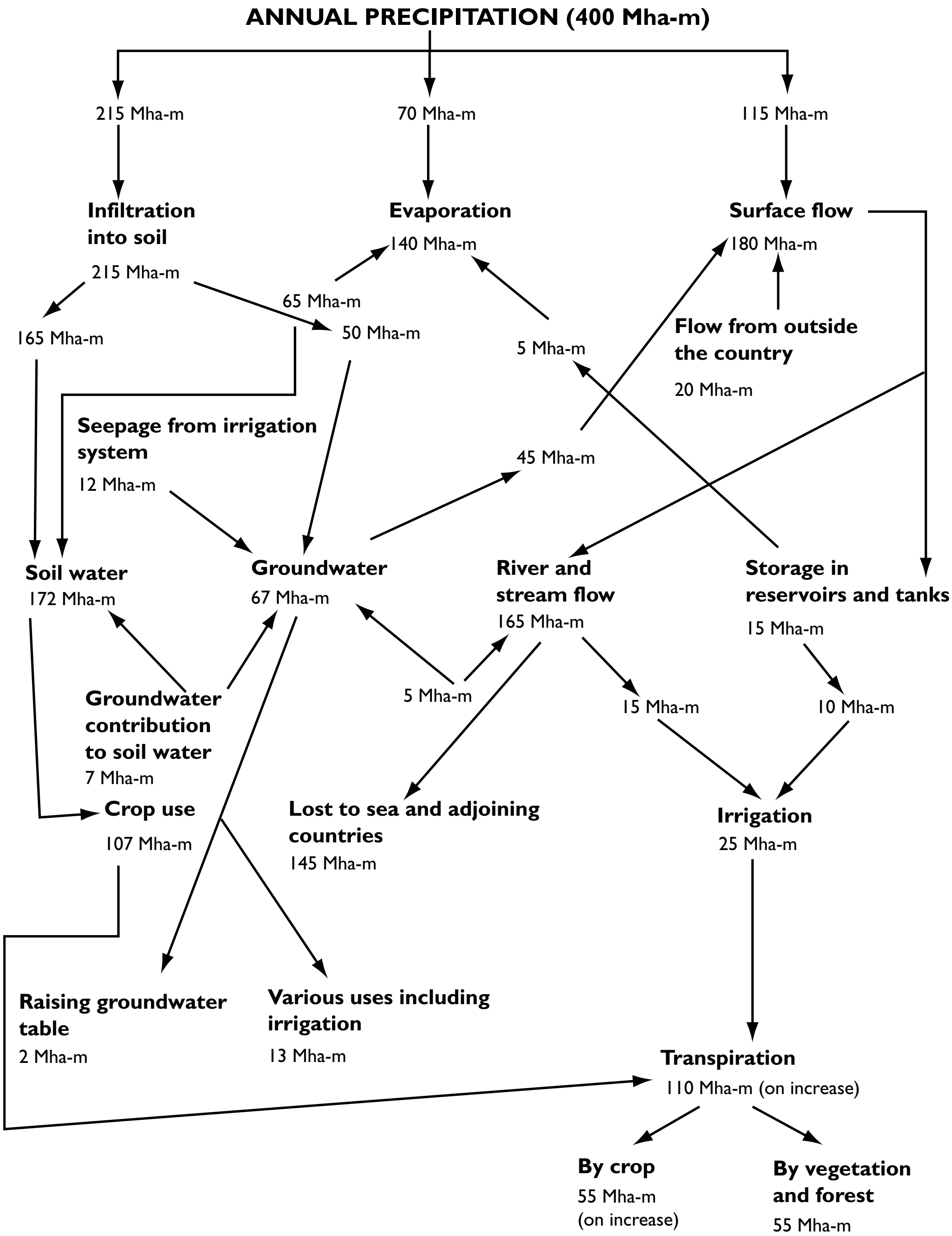

Figure 1. Annual precipitation in India (Source: Majumdar 2000).

With respect to private (farmer) fixed-capital formation in agriculture, Table 13 provides some estimates from an earlier period. It indicates that about 26% of the total private fixed-capital formation in agriculture is in irrigation assets. The rest is in other items such as farm implements, farm buildings, land improvement and orchards.

Table 13. Relative share of irrigation assets in total private fixed capital formation in agriculture, 1981–82 (all India).

Assets	Percentage share
Farm implements	46.56
Irrigation assets	25.86
Farm buildings	6.90
Land improvements	14.85
Orchards	3.49
Other	2.34

Source: Saleth (1996).

Table 14 details the distribution and trends for the different methods/sources of irrigation used in India. It shows that canals account for 31.5% of the area, and the largest share is that of wells, which account for 55.9% of the area. Among the wells, the largest share comes from tube-wells, which account for 33.4% of the area. Thus, wells—and particularly tube-wells—account for the bulk of the irrigated area as per the latest available statistics of 1996–97.

The growth rates indicate that the canal-irrigated area grew at an overall annual rate of 1.26% per year between 1971 and 1997, but within this the growth rate was found to be only 0.54% in the last 10 years (1987–97). On the other hand, tube-wells showed an overall annual growth rate of 5.35% during 1971–97, and 4.42% in the last 10 years. The growth rates indicate a rapidly increasing share of tube-well irrigation. The growth rates also indicate a small upturn in the use of private canals, tanks and other sources during the last 10 years (1987–97). These trends are indicative of growing private investment in the development of irrigation in India.

Table 15 shows the growth in number of powered wells and tube-wells over the years. It shows that tube-wells powered by electric pump sets more than doubled between 1981 and 1991, and increased by 31% between 1991 and 1998. The number of oil engines used for irrigation also nearly doubled between 1981 and 1993.

Table 14. Sources of irrigation (area in ’000 ha).

Years	Govt canals	Private canals	Total canals	Tanks	Tube-wells	Other wells	Total wells	Other sources	Total net area irrigated
1970–71	11,972	866	12,838	4,112	4,461	7,426	11,887	2,266	31,103
1980–81	14,450	842	15,292	3,182	9,531	8,164	17,695	2,551	38,720
1990–91	16,973	480	17,453	2,944	14,257	10,437	24,694	2,932	48,023
1994–95	16,799	481	17,280	3,276	17,190	11,722	28,912	3,533	53,001
1995–96	16,561	559	17,120	3,118	17,910	11,787	29,697	3,467	53,402
1996–97	16,872	480	17,352	3,343	18,433	12,392	30,825	3,623	55,143
Percentage	30.60	0.87	31.47	6.06	33.43	22.47	55.90	6.57	100.00
Growth rates									
1971–97	1.46	–2.98	1.26	–1.07	5.35	1.94	3.66	1.73	2.21
1987–97	0.52	1.08	0.54	2.24	4.02	3.81	3.93	3.34	2.59

Source: India, Ministry of Agriculture (2000 and other issues); CMIE 2000, various issues.

Table 15. Number of oil engines and electrically operated pump sets used for irrigation
(mainly powered wells and tube-wells) ('000).

Year	Oil engines for irrigation	Electric pump sets (tube-wells)
1951	65	21
1961	230	200
1971	1,815	1,621
1981	2,810	4,324
1991	4,850	9,100
1993	5,200	na[a]
1998	na[a]	11,946

[a] not available
Source: CMIE (1996); India, Ministry of Agriculture (2000).

Table 16 details the State-wise pattern of irrigation methods and shows that there is substantial variation across States. Whereas canal irrigation is substantial in States such as Assam, Haryana and Orissa, well irrigation dominates in States such as Gujarat, Maharashtra, Uttar Pradesh, Rajasthan and Punjab. Tank irrigation is important in Tamil Nadu and Andhra Pradesh, but only to the extent of about 20%. Other sources of irrigation are important in Himachal Pradesh, Assam and Kerala.

Table 17 shows the distribution of crop-wise utilisation of the irrigated area. It indicates that there is a substantial degree of diversity across crops. Whereas for crops such as wheat, sugarcane and rape/mustard, a very large percentage of the area is irrigated (86.4, 93.7 and 68.1, respectively), the percentage of area irrigated is very small for crops such as sorghum, pulses and groundnut. Rice stands at 51.1% in 1996–97, showing considerable rise from 43.3% in 1986–87. Of the total cereals and food grains area, 47% and 41%, are irrigated, respectively—indicating the substantial importance of irrigation in food grain production.

If one looks at the share of each of the crops in the irrigated area, food grains clearly dominate at 69.4%—with almost equal shares for wheat and rice at 30.5 and 30.3%, respectively. This once again brings out the tremendous importance of irrigation for food production in India. It may be noted that the shares of wheat and rice as well as food grains have shown a small decline in the last 10 years for which data are available, indicating a trend towards crop diversification. Oilseeds, fruits and vegetables, cotton and sugarcane are showing gains in their shares.

Table 16. Sources of irrigation water in selected States (% share).

State	Total canals	Tanks	Total wells	Other sources	Net irrigation area ('000 ha)
Andhra Pradesh	37.0	19.2	39.4	4.4	4,395
Assam	63.3	0.0	0.0	36.7	572
Bihar	29.6	3.2	49.5	17.7	3,624
Gujarat	20.2	1.0	78.3	0.5	3,042
Haryana	49.8	0.0	48.7	1.5	2,755
Himachal Pradesh	2.9	1.0	12.4	83.7	105
Karnataka	39.5	10.4	35.8	14.3	2,325
Kerala	30.1	13.4	23.2	33.3	357
Madhya Pradesh	29.6	3.0	54.2	13.2	6,399
Maharashtra	21.0	14.4	61.1	3.5	2,567
Orissa	45.4	14.6	40.0	0.0	2,090
Punjab	35.2	0.0	61.3	3.5	3,847

Source: India, Ministry of Agriculture (2000).

Table 16. (cont'd) Sources of irrigation water in selected States (% share).

State	Total canals	Tanks	Total wells	Other sources	Net irrigation area ('000 ha)
Rajasthan	27.5	3.7	67.8	1.0	5,588
Tamil Nadu	30.5	21.6	47.3	0.6	2,891
Uttar Pradesh	25.6	0.8	70.5	3.1	11,999
West Bengal	37.5	13.8	37.2	11.5	1,911
Others	28.5	2.5	42.1	24.9	676
All India	31.5	6.1	55.9	6.6	55,143

Source: India, Ministry of Agriculture (2000).

Table 17. Percentage area irrigated under major crops and share in total irrigated area.

Crop	% area under crop irrigated		% share of each crop in total irrigated area	
	1986–87	**1996–97**	**1986–87**	**1996–97**
Rice	43.3	51.1	32.1	30.3
Jowar	4.8	6.8	1.4	1.1
Maize	20.8	21.0	2.2	1.8
Wheat	77.3	86.4	32.1	30.5
Barley	61.8	59.9	1.2	0.6
Total cereals and millets	37.8	47.4	70.7	65.4
Gram	20.1	25.4	2.5	2.4
Total pulse	9.9	13.2	4.1	4.0
Total food grains	32.7	41.1	74.8	69.4
Sugarcane	84.0	93.7	4.6	5.3
Condiments and spices	42.1	50.9	1.8	1.9
Fruits and vegetables	36.3	41.4	3.9	4.3
Groundnut	15.4	18.2	1.9	1.9
Rape/mustard	45.0	68.1	3.0	5.8
Total oilseeds	18.6	28.2	6.2	10.1
Cotton	30.9	36.0	3.9	4.5
Tobacco	48.0	49.6	0.3	0.3
Other crops	22.3	20.0	4.9	4.2
All crops	31.4	100	38.6	100.0

Source: CMIE (2000); India, Ministry of Agriculture (2000).

Figure 2 shows the overall trend in the irrigated area. It shows that the trend is clearly upward, and the net irrigated area continued to rise even in the 1990s. The gross irrigated area is rising at a faster rate than the net area, indicating that, apart from the area, the intensity of irrigation is also increasing (in terms of more cropping seasons). Table 18 shows the details of these trends and shows that in 1996–97 (the latest year for which data are available) the percentage of gross irrigated area stood at 38.7%, and the irrigation intensity at 132.9%. The growth rate indicates that the net irrigated area has been growing at 2.61% per year in the last 10 years (1987–97), and the gross irrigated area has been growing at 2.79% per year. Both these measures are showing faster rates of growth than the overall long-term rate (1952–97), and these growth rates are much faster than those of net or gross sown area.

Table 19 presents the status on the potential and utilisation of the surface water in 1987 (Mitra 1996). It shows that the status at the 'all India' level is estimated to be only 40%, indicating that 60% of the potential is still to be utilised. There is variation across States with a range of 10% to 70%, and this may not cover the possibilities of sharing across States.

Table 20 provides an analysis of the future potential of groundwater development for irrigation across different major States in India. Overall, it shows that only about 32% of the groundwater potential has been utilised so far. However, the level varies considerably across States. The percentages are very high in the Punjab, Haryana and Tamil Nadu (93.85, 83.88 and 60.44%, respectively), indicating that a large part of the groundwater resource has already been utilised. In other States, such as Orissa, Bihar, Assam and Himachal Pradesh, it is very low at 8.42, 19.19, 4.48 and 18.10%, respectively. Gujarat, Maharashtra and Uttar Pradesh stand at 41.45, 30.39 and 37.67%, respectively. These figures indicate that in a large number of areas substantial potential exists, provided the groundwater is systematically developed and utilised.

Table 18. Trends in overall crop area and irrigated area (million hectares).

Year	Net sown area	Gross sown area	Cropping intensity (%)	Net irrigated area	Gross irrigated area	Irrigation intensity (%)	Percentage area irrigated	
							Net	Gross
1951–52	119.4	133.2	111.6	21.1	23.2	110.1	17.6	17.4
1960–61	133.2	152.8	114.7	24.7	28.0	113.5	18.5	18.3
1970–71	140.3	165.8	118.2	31.1	38.2	122.8	22.2	23.0
1980–81	140.0	173.1	123.6	38.7	49.8	128.6	27.7	28.8
1990–91	142.2	185.9	130.7	47.8	62.5	130.7	33.6	33.6
1994–95	143.0	188.1	131.5	53.0	70.7	133.3	37.1	37.6
1995–96	142.2	187.5	131.9	53.5	71.4	133.4	37.6	38.1
1996–97	142.8	189.5	132.7	55.1	73.3	132.9	38.6	38.7
Growth rate								
1952–97	0.26	0.65	0.39	2.23	2.69	0.45	1.97	2.02
1987–97	0.34	0.79	0.45	2.61	2.79	0.20	2.26	1.99

Source: India, Ministry of Agriculture (Indian Agriculture in Brief, various issues).

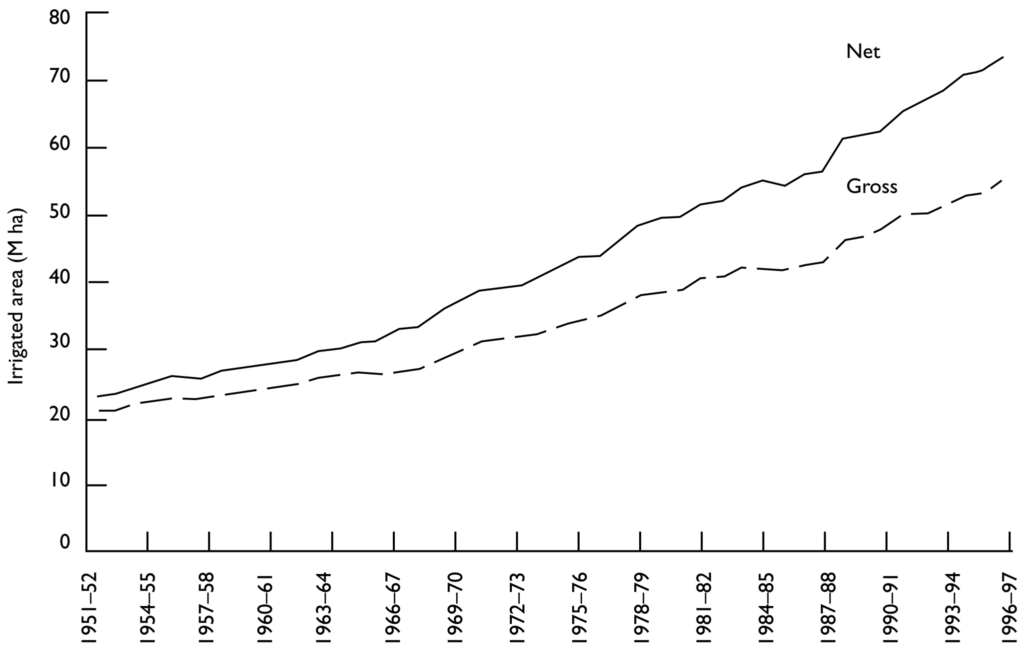

Figure 2. India: change in irrigated area over time.

Table 19. Surface water potential and utilisation 1987.

State	Ultimate potential	Potential utilised	Potential utilised as % of ultimate potential
	('000 ha)		
Andhra Pradesh	2,300	1,089	47.3
Assam	1,000	116	11.6
Bihar	1,900	753	39.6
Gujarat	347	195	56.2
Haryana	50	9	18.0
Karnataka	900	501	55.7
Kerala	800	258	32.3
Madhya Pradesh	2,200	598	27.2
Maharashtra	1,200	712	59.3
Orissa	1,000	363	36.3
Punjab	50	5	10.0
Tamil Nadu	1,200	839	69.9
Uttar Pradesh	1,200	285	23.8
West Bengal	1,300	769	59.2
All India	17,378	7029	40.4

Source: Mitra (1996).

Table 20. Groundwater potential and level of development.

State	Utilisable groundwater for irrigation (Mha-m/year) (net)	Level of groundwater development (%)
Andhra Pradesh	2.70	23.64
Assam	1.89	4.48
Bihar	2.56	19.19
Gujarat	1.56	41.45
Haryana	0.65	83.88
Himachal Pradesh	0.03	18.10
Karnataka	1.29	31.26
Kerala	0.59	15.28
Madhya Pradesh	3.89	16.49
Maharashtra	2.29	30.39
Orissa	1.53	8.42
Punjab	1.51	93.85
Rajasthan	0.96	50.63
Tamil Nadu	2.02	60.44
Uttar Pradesh	6.41	37.67
West Bengal	1.77	24.18
All India	32.47	31.92

Source: India, Ministry of Water Resources (1997).

Analysis of Growth in Irrigation

This section analyses growth in the irrigated area using an investment model developed in Gandhi (1990) and Gandhi (1996) and based on earlier work by Jorgenson (1967). Time series data on total or private investment in irrigation are not available, and hence irrigated area is used as an alternative dependent variable.

The model is essentially based on maximisation of the function given below, which represents maximisation of profits over time:

$$\text{Net present value} = \int_0^\infty e^{-rt} \begin{bmatrix} \mathrm{P}(\mathrm{t})F\left[KP(t),KG(t),IA(t),ED(t),L(t),FR(t)\right] \\ -W(t)L(t)-PF(t)FR(t)-PED(t)ED(t) \\ -PK(t)\left[IA(t)+\delta IA(t)\right] \end{bmatrix} dt$$

where,

P = price of output,

F(.) = production function,

KP = private capital stock,

KG = government capital stock,

IA = irrigated area (total gross),

L = labour use,

FR = fertiliser use,

ED = energy use (electricity and diesel),

W = wage in agriculture

PF = price of fertiliser,

PK = price of capital, esp. for expanding irrigation

PED = price index of energy (electricity and diesel)

d = rate of depreciation

r = interest rate, and

t = time.

Following derivation along the lines described in Gandhi (1996), the following function is obtained for estimation:

$$IIA = \left(cons\tan t\right) P_t^{\gamma 2}\ KG_t^{\gamma 3}\ KP_t^{\gamma 4}\ UC_t^{\gamma 5}\ W_t^{\gamma 6}\ PF_t^{\gamma 7}\ PED_T^{\gamma 8} + \\ +\ b_1 RS_t + b_2 CRCP_t + b_3 CRCB_t + RAIN_T + b_4 IA_{t-1} + u_t$$

where,

IIA = increase in irrigated area (gross),

UC = user cost of capital,

RS = rural saving,

CRCP = cooperative credit,

CRCB = bank credit, and

RAIN = rainfall.

A non-linear estimation procedure proved somewhat unstable and hence the function was estimated for the present in a linearised form. Time series data from 1952–53 to 1992–93 from official sources were used for the estimation. The results are given in Table 21.

The results indicate that both government capital stock and private capital stock play a very significant and important role in determining increase in irrigated area. Thus, government and private investment in agriculture have a major impact on progress in irrigation. Amongst other variables, rural savings and cooperative credit are also found to have a significant impact. This indicates the important role of institutional credit in influencing growth in irrigation.

It is also found that the price of energy, which includes both electricity and diesel, has a very significant negative impact on growth in irrigation. This confirms the frequent observation in literature that energy pricing, particularly that of electricity, has a significant influence on irrigation. The wage rate is also found to have a significant negative impact, indicating the influence of wages through the large labour component required for the development of irrigation.

Table 21. Regression results: irrigation models.

Variable	I			II		
	Estimated coefficient	**t-stat**	**Significance**	**Estimated coefficient**	**t-stat**	**Significance**
PAG	0.054374	1.470		–0.003950	–0.090	
QAT	0.000097	1.113		0.000094	1.133	
KG	0.000355	1.858	*	0.000389	2.153	**
KP				0.000966	2.161	**
UC	0.066986	1.931	*	0.036879	1.040	
WAG	–0.880590	–2.280	**	–0.142830	–0.287	
PF	0.005377	0.328		0.017744	1.078	
PED	–0.018395	–2.469	***	–0.015073	–2.102	**
RSD	0.000359	2.004	**	0.000316	1.860	*
CRCID	0.003856	2.437	**	0.002365	1.441	
CRBID	–0.002009	–1.653		–0.000786	–0.616	
RAIN	–0.000567	–0.380		0.000032	0.023	
LIAG	–0.413080	–4.127	***	–0.946570	–3.582	***
CONSTANT	7.143200	2.729	***	–6.838000	–0.988	
R-Square	0.6365			0.6901		
Durbin-Watson	2.1715			1.9878		

[a] Variables: PAG = price of agricultural output; QAT = agricultural output; KG = government capital stock in agriculture; KP = private capital stock in agriculture; UC = user cost of capital; WAG = agricultural wage; PF = price of fertilisers; PED = price of electricity and diesel; RSD = rural savings; CRCID = cooperative credit to agriculture; CRBID = commercial bank credit to agriculture; RAIN = rainfall index; LIAG = lagged increase in irrigated area (gross).

[b] Significance: * = 90%; ** = 95%; *** = 99%.

Emerging Institutional Issues

> 'There is an intimate connection between the institutions and technology employed, (and) the efficiency of a market (economy) is directly shaped by the institutional framework.'
>
> Douglass C. North (1997)

The management of resources, particularly water resources, poses a major challenge for sustainable agricultural development in India and elsewhere. Often, standard neo-classical theory has little to offer in terms of practical and durable solutions. Determining the right price for the water hardly solves the problem since it is in implementing the pricing and cost recovery that the major problem lies (Gandhi 1998). Evidence on this and other institutional issues is presented below.

Studying institutional imperatives for large irrigation systems in India, Reddy (1998) has found that pricing and other market mechanisms are hardly a panacea for the ills of irrigation systems. The paper is based on data from 181 households from 12 villages belonging to 3 varied districts of Rajasthan. The villages differ in their access to irrigation—some are within the command area of the Chambal project. Both rapid appraisal and survey methods were used, including a contingent valuation method to assess willingness to pay (WTP). Factors influencing the WTP were also assessed through regression analysis. The study found that the farmers are willing to pay 2–3 times the price for water than the prevailing public water rates, provided that the government supplies water in sufficient quantity and in a timely fashion. However, there are inter-regional, intra-regional and inter-crop variations. WTP is linked more to the scarcity of water than the ability to pay. WTP exceeds the operation and maintenance (O&M) costs in the Chambal command area. It increases with the farm size and is therefore positively linked with the economic status. Regression results indicate that households availing of low-priced public irrigation are willing to pay less than those dependent on private irrigation (indicating a 'free rider' attitude). Scarcity of water leads to a higher WTP, and the greater the proportion of area irrigated the higher the WTP.

Reddy (1998) indicated that, even though the study showed that pricing of water on a cost basis is feasible, it may not lead to efficient allocation and financial viability, since under the existing institutional arrangements, recovery rates are very low (27–70%) and would not be helped by higher water rates. Irrigation departments need to have authority and autonomy and need to implement volumetric pricing. When water is scarce, water markets lead to inequitable distribution, and State intervention is necessary. Institutional mechanisms such as users' associations, farmer participation, and turning over irrigation systems to farmer groups should be promoted for the distribution of water. Non-government organisations (NGOs) should be involved to promote water users' associations that have incentives to manage the system efficiently and to collect irrigation fees from the individuals. This would improve fee recovery and system viability, and overcome the difficulty of high transaction costs in the efficient management of this resource.

In another interesting study, Singh and Tewari (1998) examined institutional issues with respect to groundwater. They studied the role of various organisations/institutions engaged in assessment, development and control of the groundwater resource in the State of Uttar Pradesh, as well as their performance in maintaining groundwater levels. The institutions covered included the Central Ground Water Board, the State Ground Water Organisation, National Bank for Agriculture and Rural Development, Intensive Rural District Programme (IRDP), Jawahar Rojgar Yojna and Command Area Development Programme. Measures to prevent over-exploitation include demarcation of blocks (white, grey and dark zones), restriction of loans, restriction of subsidies, restricting energisation and spacing criteria. A Model Bill has also been circulated by the Government of India, but this is enforced by only a few States. The study found that, even though these institutions have played an important role, there is little control on private investment. The number of private tube-wells increased by about 200–300% in all regions of the State between 1979/80 and 1992/93, and even the number of government tube-wells increased substantially. The water balance in terms of the gap between normative demand and actual net draft in all regions is negative and worsening. Apart from lowering the watertable, this is reducing tube-well discharge and increasing the cost of irrigation. The authors suggest conjunctive use, reducing losses, use of water saving, irrigation technology, legislation, shifting cropping patterns away from high water-use crops, and an effective organisational structure of the farmers to monitor private investment in tube-wells.

Dhanasekaran (1998), studying the distribution of irrigation water in the Periyar Vaigai project, found that the performance of such large-scale surface irrigation projects is unsatisfactory since organisational aspects are neglected. The tail reach, in particular, suffers inadequacy in deficit years and untimely supply during normal years. If the organisation strictly adheres to timely scheduling—thereby reducing uncertainty—and releases water for only one crop in deficit years, then the performance would be greatly improved. Developing conjunctive water use would also help. In another interesting paper, Datta (1998) found that curative measures such as sub-surface drainage (SSD) are required to tackle the problem of waterlogging and salinity. But because of its indivisible nature, the technology requires collective action which calls for new institutional arrangements. Such an arrangement is demonstrated for SSD by the Haryana Operational Pilot Project in which a special farmers' participation section was created to ensure awareness-building and a good rapport with the villagers, including the Sarpanch, progressive farmers and other stakeholders. The project was organised in blocks of 50 ha each (which was considered optimum) and a written agreement with the farmers was also made. The mid-term review found the participation very useful and operation and maintenance was turned over to Farmers' Drainage Societies.

Gauraha and Sharma (1998) studied the role of organisations and institutions in the development of Sargipal watershed in the tribal Bastar district of Madhya Pradesh. Secondary information and primary data from 60 randomly selected farmers as well as officials, local leaders and NGOs were collected. The data showed poor awareness about and poor participation in the project. There was also lack of coordination among the departments and the supervising authority. As a result, most of the common-pool resources were degraded. The authors suggested that the government should confine itself to provision of technical and financial support and create an environment in which farmers and common pool resource (CPR) user organisations can work effectively. On the issue of well irrigation, Khodaskar (1998) found that it increases the cropping intensity and changes the cropping pattern, enabling farmers to take more profitable crops, such as sugarcane and vegetables. It helps to improve incomes, infrastructure and reduces out-migration.

Srivastava and Singh (1998) examined the Free Boring Scheme of the Uttar Pradesh Government for the small and marginal farmers who were believed to be deprived of irrigation. A before–after study was done with a sample of 50 beneficiaries from 2 blocks. It found that the scheme did not bring any additional land under irrigation, as the land was already being irrigated by hiring. However, sugarcane area (at the cost of wheat and rice), fertiliser use, number of irrigation, yields and profits increased. The scheme was really not 'free' since significant additional investment by farmers was required, making the benefits–costs non-viable in one block and barely viable in another.

Saleth (1996) indicated that India is heading for a water crisis unless policies and institutions are radically transformed and reoriented. He indicates that the fundamental problem of the water economy is neither the utilisation gap nor the irrigation gap, but it is the incentive gap—the gap between the real economy value of water and the value underlying the irrational use of the resource. He argues that there is an urgent need to search for more durable solutions, though they may be politically and administratively difficult, such as the institution of a water-rights regime which can effectively limit and regulate both individual and collective water withdrawals from surface and sub-surface sources. Kumar (2000) wrote that, in the absence of a well-defined property rights structure, increased use of groundwater by a few will undermine local management efforts. Communities need to establish rights over the resource and regulate demand to manage groundwater sustainably.

Saleth and Dinar (1999), based on a cross-country study on the water challenge and institutional response indicated that instead of isolated attempts on single dimensions of the water problem, an integrated approach is required. At the heart of the integrated approach should lie institutional change to modernise and strengthen the legal policy and administrative arrangements governing the water sector as a whole.

Svendsen and Gulati (1995) indicated that sub-optimal functioning of the extensive irrigation network of major and medium irrigation schemes in India has made it imperative for attention to be specifically focused on the problems of generating sufficient funds for proper maintenance of the system. In addition, the focus need to be on the development of institutions or organisations that can function independently on a long-term basis.

Brewer et al. (1999) discussed the problems of water users' associations, seen as one institutional option. They indicate that, even though there was a major concern among the government officials, no evidence was found to indicate that water distribution becomes more inequitable after management is transferred to water users' associations. In most associations in medium and large canal systems, water deliveries have become more predictable and users face fewer problems in obtaining irrigation water. Lengthy application processes and related irregularities are avoided. However, organisational costs are a major constraint to increase participation of users, and new institutional frameworks are required to reduce these.

Vaidyanathan (1999) indicated that evolving appropriate institutional arrangements is fundamental to solving the water resource management problem. He wrote that privatisation and market allocation of such a basic common pool resource such as water is neither feasible nor desirable, and therefore the government must play a major role, but one which is very different from its current character. It needs to involve user representatives in system management. While the broad directions of the necessary institutional reform are reasonably clear, working out its details and implementing them is far from easy. The design of appropriate institutions in the face of variations in environment, agrarian structure and other related aspects is complex and engineering the reforms is even more difficult.

Shah (1993), studying groundwater markets, indicated that a new set of policy instruments is required to manage groundwater development. He stated that the nerve centre of groundwater development is not groundwater corporations, departments or boards, but the State electricity boards, since it is the supplying of and charging for power that can have the most important impact. He wrote that the key problem in India's irrigation sector is of building modern, forward-looking, imaginative organisations/institutions with high levels of management capacity. Foster et al. (2000) showed the key linkages between groundwater and rural development, and indicated the great need for identifying appropriate technical and institutional approaches for improving reliability of water wells and the sustainability of the groundwater resource.

Svendsen and Rosegrant (1994), studying irrigation development in Southeast Asia, indicated that three basic shifts are occurring in concepts related to irrigation. The first is of viewing water/irrigation as an economic good rather than a social good. The second shift is of viewing irrigation development not simply as constructing irrigation facilities, but as providing irrigation water to farmers. The third is a further shift to seeing irrigation systems as providing an irrigation service to farmers.

Meinzen-Dick and Mendoza (1996) indicated that growing water-scarcity problems and competition between uses and users of water pose a serious policy challenge to policy-makers in India. The dominant role of the state in the management of water resources has been rationalised based on its public good character. However, low recovery of costs and mounting costs of developing new sources of water, besides problems of quality of service, are leading to a search for alternatives to increase the efficiency of water management. Meinzen-Dick and Mendoza (1996) indicated that user-based allocation is generally more flexible, but the high transaction costs for organising users to develop irrigation systems and allocate water is a problem. Property rights for water are important for group action to provide the necessary authority for allocation. Market allocation has advantages in providing incentives for highest value applications of scarce water resources. An examination of the structure of rights and incentives is called for.

In discussing design of water institutions, Livingston (1993) indicated that, in the case of water resources, many of the assumptions under which markets yield accurate incentives and foster efficient resource use are violated. This is because water is fugitive, lumpy and rife with externalities. Besides, it is non-rival, entails substantial transaction costs and equitable distribution in the utilisation of this suffers from information deficiencies. For the market to function efficiently:

- the resource user must be certain of the quantity, quality, location and timing of resource availability;
- the resource must be perfectly divisible; and
- the resource use must not affect or be affected by utilisation of the resource by another party.

According to Livingston (1993), these conditions are not met, in the case of water resources, in the absence of institutional control. Thus market failures are endemic to water resources and institutional control is essential. Designing institutions to deal with the physical peculiarities of water in a way that is established, offers sensible incentives and enables efficient resource use is, however, not easy.

Ostrom (1992) stated that control and use of water—a constantly moving, flowing resource—is an endlessly challenging task. She indicated that the development of adequate physical capital is of course a necessary step in achieving benefits, but many technically advanced irrigation systems have failed and many disappointing investments have resulted from institutional failures. Crafting of institutions is an ongoing process must directly involve the users and suppliers of an irrigation system. Crafting institutions for irrigation systems is challenging and requires skill in understanding how rules combine with particular physical, economic and cultural environments to produce incentives and outcomes. It requires bringing together both the formal and the informal as is described in Figure 3.

Principal Questions Arising

The above review and analysis indicates that significant problems of an institutional nature exist in the case of water management. Given the importance of water as a primary and scarce resource for agriculture on which, in India, nearly two-thirds of the people depend directly or indirectly for their incomes, the following questions become of significant national importance:

How can the institutions related to the utilisation and control of water resources be designed so that the use reflects the real scarcity of the resource and leads to its efficient use?

How can the institutions related to the utilisation of water resources be designed so as to achieve an resource?

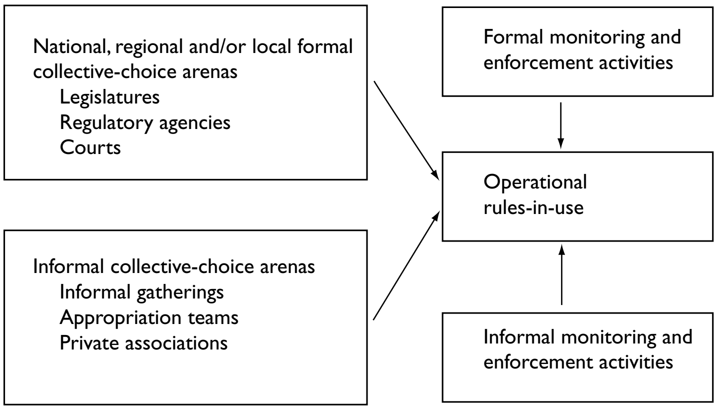

Figure 3. Relationship between formal and informal collective-choice arenas and operational rules-in-use. Source: Ostrom (1992).

How can institutions be designed to achieve desirable rates of investment in irrigation and generate the necessary financial resources?

How can institutions be designed to develop and utilise water resources in such a way that ill effects on the soil and the environment are minimised?

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Subsidies and Reforms in Indian Irrigation

Ashok Gulati* and Sudha Narayanan†

Abstract

In this paper, reforms in Indian irrigation are discussed with particular emphasis on pricing. The concept and magnitude of subsidies with respect to Indian public irrigation are explored, and the difficulties in the reform process are discussed. These difficulties include the 'catch 22' situation whereby it is difficult to improve the quality of services without funding, but it is difficult to collect revenue through service fees when service quality is so poor. Public sector inefficiencies are also a problem. The situation offers an opportunity for reform that should be considered a win–win situation for the farmers and policy-makers. Some practical options for improving the performance of the irrigation sector are discussed.

SUBSIDIES in general, and for agriculture in particular, are often an eyesore to development funding agencies. Developing countries that approach these agencies for loans under structural adjustment programs are often advised to get rid of these subsidies as early as possible. The government in power does agree to phase-out the subsidies, and in fact tries to do so. But the failure rate in this area has been high. India is no exception to this. It may be as much due to the proverbial 'lack of political will' as it is to lack of proper understanding of the subsidies.

This paper[1] attempts to dig a little deeper, to understand the concept and magnitude of subsidies in Indian public irrigation. It also reviews the changes over the last five decades. The attempts to reform these subsidies in the light of what various expert committees have been saying from time to time are also visited. But the key question that this paper tries to answer is: how can one increase the probability of success of such reforms? What would be the general or specific principles in the reform process that could help raise the chances of success in this direction? These are the focal points of this paper.

As an introductory note to Indian irrigation, the second section provides an overview of the development of irrigation sector in the country over the last five decades. The third section elucidates the concept, method and estimates of irrigation subsidy. The fourth section briefly examines the ramifications of these irrigation subsidies in different spheres, environments, finances of the government and input-suppliers, on equity and so on. In the fifth section, the discussion stresses on the need for reform while the sixth section attempts to plot desirable elements of such reform. The final section recapitulates the main points of the paper.

Overview of the Irrigation Sector in India

In a recent assessment, India's ultimate irrigation potential (UIP) is estimated to be 139.9 million ha: of this, the contribution of groundwater irrigation is 64.05 million ha (earlier 40 million ha) and that of minor surface irrigation is 17.38 million ha (up from an earlier 15 million ha). The contribution of major and medium irrigation schemes remains the same (58.5 million ha).

Irrigation has occupied a pre-eminent position in India's agricultural strategy and this is reflected in the fact that, during the past 45 years, starting with the first Five Year Plan (FYP) in 1951–52 to 1996–97, the nation has spent almost Rs920 billion at historical prices on irrigation (Table 1). Major and medium schemes dominate cumulative expenditure (at 57%)

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[1] This paper draws heavily on Gulati and Narayanan (2000), Rao et al. (1999) and Gulati and Chopra (1999).

and are followed by minor irrigation (32%), command area development (CAD) (6%) and flood control (5%)[2]. Over this period, the average annual expenditure (investment) on major and medium irrigation schemes has always been higher than that on minor irrigation (at constant prices, base: 1996–97), except briefly during the annual plan period 1966–69 and fourth plan period 1969–74. Investment in minor irrigation (from public and institutional sources) accounts for only 55.4% of that in major and medium irrigation schemes, at both current and constant prices (institutional investment in minor irrigation was 46% of all investment in this minor irrigation sector).

[2] This includes the expenditure by the government and from institutional sources, but excludes the expenditure financed from farmers' own resources, on major and medium irrigation, minor irrigation, command area development (CAD) and flood control. At 1996–97 prices, this figure stands at a staggering level of Rs2313.87 billion (GOI 1997).

Table 1. Magnitude and composition of investment through plan periods in irrigation and flood control sectors (Rs million).

Plans	Major and medium irrigation	Minor irrigation State (a)	Institutional (b)	Total (a+b)	Command area development	Flood control (State & Central)	Total
First (1951–56)	3,762	656		656		132.1	4,550.1
Second (56–61)	3,800	1,422	194	1,616		480.6	5,896.6
Third (61–66)	5,760	3,261	1,154	4,415		820.9	10,995.9
Annual (66–69)	4,298	3,213	2,347	5,560		419.6	10,277.6
Fourth (69–74)	12,423	5,062	6,611	11,673		1,620.4	25,716.4
Fifth (74–78)	25,162	6,275	7,988	14,263	1,476	2,986.0	43,887.0
Annual (78–80)	20,786	4,962	4,804	9,766	2,153	3,299.6	360,04.6
Sixth (80–85)	73,688	19,793	14,376	34,169	7,431	7,868.5	123156.5
Svnth (85–90)	111,073	31,319	30,610	61,929	14,475	9,415.8	196892.8
Annual (90–91)	26,348	8,122	6,756	14,878	2,856	1,967.3	46049.3
Annual (91–92)	28,240	8,441	6,740	15,181	3,338	2,637.1	49396.1
Eighth (92–97)	224,145	59,773	51,190	110,963	25,101	16,233.7	376442.7
Annual (92–93)	30,471	9,946	8,115	18,061	3,228	3,301.6	55061.6
Annual (93–94)	35,714	10,483	8,756	19,239	3,749	3,660.0	62,362.0
Annual (94–95)	41,591	11,852	10,035	21,887	4,221	3,078.2	70,777.2
Annual (95–96)[a]	44,996	12,168	8,839	21,007	4,373	3,567.0	73,943.0
Annual (96–97)[b]	70,813	17,164	14,400	31,564	5,061	4,185.5	111,623.5
Total (using annual plan figures)	538,925	154,139	131,725	285,864	52,361	49,440.2	926,590.2

[a] anticipated; [b] target.
Source: Water and Related Statistics, Central Water Commission, July 1998.

As a result of these expenditures, there has been continuous growth in both potential and actual utilisation of irrigation throughout the plan periods. However, much potential remains to be tapped, since the level of achievement continues to be significantly less than the UIP.[3]

Under these circumstances, it is of some concern that the importance of irrigation investment relative to other sectors seems to be coming down over time, as is reflected in the relative allocations for this sector (Rao et al. 1999). For instance, the percentage share of irrigation in total plan expenditure has diminished from 23% in the first FYP to only 7% in the eighth. Correspondingly, the percentage of total expenditure on major and medium irrigation projects in the total plan expenditure declined from 19% in the first FYP to 5% in the eighth.

This declining trend in plan outlays casts doubts regarding the further development of this segment of the irrigation sector in India. In addition to financial pressures, the rising capital cost of irrigation development, inadequate maintenance, and the consequent deterioration of existing irrigation networks make the realisation of the country's UIP even more doubtful by 2010, a target set by the planners in earlier plans (GOI 1996; Rao et al. 1999).

Irrigation Subsidy

Concept and quantification

The issue of irrigation subsidy must be placed within the larger context of irrigation development in India. How does one define 'irrigation subsidy'? One of the ways is to go by the supply side theorising; that is, to look at what it costs the system to deliver irrigation water to the fields and how much of this cost the farmers pay. The difference between the cost and the revenue received from farmers can be defined as the irrigation subsidy to farmers. While this approach is perhaps better than the demand side theorising of subsidy[4], the real problem is confronted in defining the cost of irrigation. The marginal cost principle would suggest that the pricing of water be based only on the variable costs (operation and maintenance costs). If this is accepted, the next problem that crops up immediately is how to recover the massive fixed costs (capital costs) of public irrigation. There are also issues related to 'which capital cost: the one incurred at historical prices or the replacement cost at current prices?' Depending

3. As a result of these massive expenditures, India added about 66.71 million ha to its pre-plan period irrigation potential of 22.6 million ha, thus reaching a cumulative figure of 89.31 million ha of irrigation potential by 1996–97. Of this created potential, about 80.5 million ha were being utilised, according to the Ministry of Water Resources. (An alternative figure on land-use statistics from the Ministry of Agriculture revealed that the gross irrigated area in the country was 70.64 million ha in 1994–95, the latest year for which the information is available). This suggests that further research in this area is required to reconcile the information on basic numbers emanating from different sources of the Government of India. On the other hand, it is interesting to note that irrigation potential from minor irrigation has touched 63% of total irrigation potential in the country, thus making it a 'major' source of irrigation.

The trend of cumulative development of 'potential' and 'actual utilisation' from major and medium irrigation schemes, beginning from the pre-plan period until the latest eighth plan period, 1992–97, and its comparison with the ultimate irrigation potential (UIP) in India shows continuous growth in both potential and actual utilisation of irrigation, throughout the plan periods. A major noticeable feature is the growing gap between the potential and actual utilisation of irrigation from major and medium schemes, especially since the fourth FYP period, indicating a decline in efficient utilisation of irrigation facilities. By 1992–97, the actual utilisation of irrigation from such schemes was 85.6% of the potential and the potential itself was lower than the UIP of 58.5 million ha by 44%. For minor irrigation, the gap between 'potential' and actual utilisation has been negligible throughout the 1950s, '60s and '70s. However, from the sixth FYP period, we observe an emerging gap which expands as we reach the eighth plan period. However, the gap in this case is smaller than the gap between potential and actual utilisation from major and medium irrigation schemes. By the eighth plan period, the actual utilisation of irrigation from minor schemes constituted approx. 92% of the potential, indicating a higher efficiency level as compared with larger schemes. The cumulative potential from minor irrigation is itself lower than the UIP from minor irrigation by approximately 30%, which is less than the difference (44%) between UIP and potential from major and medium schemes.

upon which principle one uses, the estimates of irrigation subsidy can differ widely (Gulati et al. 1995a,b).

However, in India, an expert committee which reported (GOI 1992) on the pricing of irrigation water, suggested that pricing of canal irrigation water must cover all the operational and maintenance expenses and 1% of cumulative capital expenditures incurred in the past at historical prices. The suggestion of charging 1% of cumulative capital expenditures at historical prices from farmers was considered by the committee as a transition phase. The committee suggested that, in due course, full capital costs should be recovered from the farmers. If one accepts the principle of charging 1% of the cumulative capital expenditures (at historical prices) from the farmers along with operational and maintenance costs, the subsidy figures for public irrigation (costs minus revenue received from the farmers) turn out to be around Rs51 billion in the year 1999–2000 (Figure 1).[5]

Region-wise, it emerges that the northern, western and southern regions account for a larger share of the irrigation subsidies as compared with the eastern region (Figure 2). The share of the southern region (Andhra Pradesh, Karnataka, Kerala and Tamil Nadu) increased from 21% in 1982–83 to 25% in 1999–2000 (projected) as also did the northern region from 26% to 30% during the same period. While the share of the eastern region declined from 19% to 13%, the western region (comprising Gujarat, Maharashtra, Rajasthan and Madhya Pradesh) has a share of around 27%. The western region has maintained so high a share possibly because the costs of canal irrigation are much higher in this region due to undulating terrain. It must be emphasised at this point that the coverage for the computation of subsidies is incomplete since information is not available for all the States in all the years.

Consequences of Irrigation Subsidies

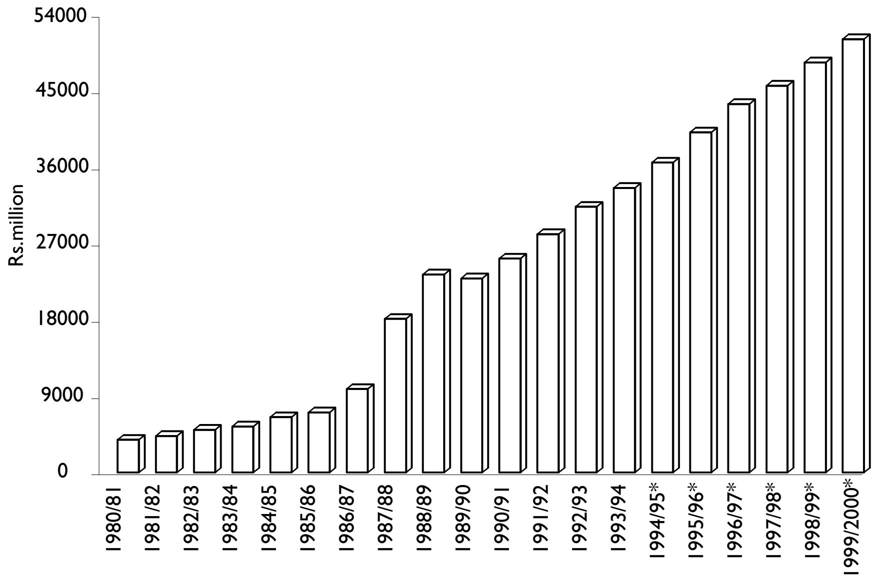
Financial and economic consequences

What is often brought out in the literature on the subject is that the farmers have never paid the full cost of canal irrigation. The pricing of canal water is very low and totally unrelated to the productivity or scarcity value of water or the cost of delivering it. It accounts for just 8% of the cropping expenses and equals barely 5% of the average incremental production of irrigated areas over rainfed lands (World Bank 1999a). Moreover, water charges are fixed in nominal terms that remain unchanged for years, so that in real terms water charges have been falling over that period. While irrigation rates for surface water have either remained static or increased only marginally over a long period, the farmers' capacity to pay for the irrigation service has improved substantially. This can be attributed to a combination of benefits from high-yielding technology and rising prices of agricultural commodities. In fact, the net benefits of canal irrigation exceeded the full cost of canal irrigation by a fair margin during 1980–81 to 1992–93 (Dhawan 1998), although the margin has declined from 114% at the beginning of the period to 57% at the end of the period. This is mainly because farm product prices have lagged behind the cost of canal irrigation. The fact that farmers do not pay the full cost of canal irrigation, despite the net benefits accruing to them, indicates that they have been able to corner large rents (Repetto 1986).

Apart from the problem of low water rates, collection of the existing water rates is very poor. In most States it is the responsibility of the revenue department, implying that the agency levying the water charges and those responsible for its collection are usually different. Collection has tended to remain low with even water charges not fully collected; and most States have plunged into huge arrears. The overall loss amounts to around 7% of the total plan expenditure on all irrigation schemes. The inability to recover costs has led to a growing State revenue deficit so that irrigation alone is currently responsible for one third of a State's revenue deficit (Oblitas and Peter 1999).

[4] The demand-side approach would measure irrigation subsidy as the difference between the marginal value product of irrigation water (willingness to pay) and what the farmer actually pays for it.

[5] This includes major and medium irrigation as well as minor public irrigation. However, it excludes the power subsidy that goes to operate tube-wells/wells etc. for irrigation. It must be acknowledged that this method is far from ideal. In this context, several alternative methods have been discussed which take into account (to varying degrees) aspects such as investment expenditure, depreciation, gestation lags etc. For details on estimation methods see Dhawan (2000), Gulati and Narayanan (2000), Gulati and Chopra (1999), and Gulati et al. (1995a). Even in this method the choice of one percent of cumulative capital cost is highly debatable and arbitrary. But this was decided on unanimously by the Vaidyanathan Committee based on the 'Delphi principle'.



Notes: Irrigation subsidy is computed as O&M + 1% cumulative capital costs at historical price—receipts of major, medium and minor irrigation. * indicates that estimates for these years are based on projected values. Coverage is staggered.

Figure 1. Subsidies on major, medium and minor irrigation (1980/81 to 1999/2000).

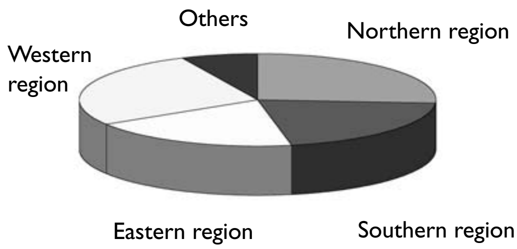


Figure 2a. Regional shares in irrigation subsidies, 1982–83.

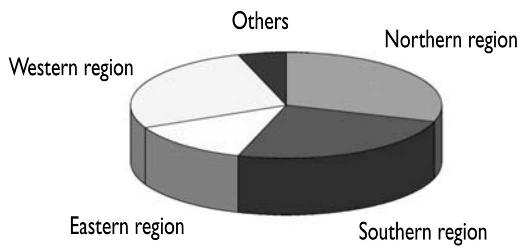


Figure 2b. Regional shares in irrigation subsidies, 1999–2000.

With inadequate cost recovery and inability to generate funds, the irrigation departments have to rely on the State government to meet even their operations and maintenance. Since irrigation subsidies have to be absorbed at the State level and the budgetary situation of most of the States is under severe strain, it has resulted in increasing cuts in further expenditure on irrigation by the state. The subsidy on surface irrigation on account of non-recovery of operational and maintenance expenses represents only a lower bound of irrigation subsidy. When the annualised, amortised cost of capital deployed on major and medium irrigation schemes is also considered, the subsidy level is even higher. One such estimate that uses the interest rate on long-term government securities as the relevant interest cost of historical capital costs, amounts to Rs118 billion during the seventh FYP which exceeded the plan's expenditure on major and medium irrigation of Rs110 billion (GOI 1992). Thus, a subsidy reduction of 20% could have helped raise expenditure by at least 20%. Alternatively, a subsidy reduction of even, say, 5% in 1986–87 would have doubled expenditure on operations and maintenance of Rs4.93 billion incurred that year. This would have entailed an over three-fold rise in the collection of gross revenue from the farmers in that year, i.e. Rs167 billion (Vaidyanathan 1993).

The result of curtailed expenditure on irrigation is the poor maintenance of the projects and neglect of existing irrigation systems (leading to poor quality of service) on the one hand, and the inability to complete on-going projects because of paucity of funds, on the other.

Physical constraints

Inadequate budgetary allocation for operation and maintenance of irrigation systems has led to rapid deterioration of physical infrastructure. The surface irrigation facilities and drainage infrastructure are in a poor state. Although this is partly due to poor design and construction, it is to a larger extent a result of lack of adequate maintenance. Broken down distribution systems, silting of canals and drains etc. tends to reduce irrigation efficiency and lead to irregular supply. Ultimately, the extent of the irrigated area is far less than envisaged[6]. In addition, physical deterioration of hydraulic systems leads to waste of irrigation water due to conveyance losses, unreliable or untimely deliveries and application losses (World Bank 1999a).

Wastage and inefficiencies in water use

The total UIP of the country, now stated to be about 139.9 million ha, suggests that there is scope for further exploitation. However, the sustainability of even existing irrigated agriculture in several tracts of the country has been under a cloud, making doubtful the much-needed continuance of high levels and rates of growth of production in the future. Such a threat becomes imminent when the quantity and quality of the natural capital is itself eroded through poor allocation mechanisms. A subsidy regime, among other things, distorts prices and the consequent allocation of the water resource as between the present and the future. A flat-rate pricing structure of canal waters on a crop area basis implies that the marginal cost of water to the farmer is almost zero. Theoretically, it induces the farmer to use the water until the marginal product of this input becomes zero, leading to water consumption in excess of the level that would be maintained if it were priced on the basis of its opportunity cost. The zone of water consumption between the points where its marginal product equals its opportunity cost and when it touches zero, is the zone of increasing inefficiency in the use of water. Empirically, it is somewhat difficult to accurately measure the marginal value product of canal waters. Nevertheless, a broad indication can be had. It is estimated, for instance, that canal irrigation increases agricultural production by about 70% (over non-irrigated cultivation). The contribution of water is generally taken to be about a quarter to two-fifths of the additional agricultural production. When the farmer uses water as an input until its marginal value product is zero (since the marginal cost of water to the farmer is close to zero), he overexploits the resource. This leads to large-scale emergence of water-intensive crops like paddy or sugarcane in irrigated tracts. It is well known that in almost all the canal commands, the actual area under

6. There is a widespread feeling that several of the irrigation schemes, especially major and medium ones, have turned out to be much less beneficial than had been projected in the feasibility reports. The ex-post cost–benefit ratios of several of these schemes are way below the ex-ante expectations. The costs have risen, and benefits have fallen short of expectations. In some regions, this is supplemented by the awareness of new environmental costs. Moreover, whatever benefits have accrued, they have been mopped up by a small group of farmers on irrigated tracts.

paddy or sugarcane turns out to be much more than is initially planned in the project. With respect to surface water, in addition to distorted pricing in the form of low water rates, the absence of financial accountability on the part of project authorities leads to wastage of water both before and after it reaches the fields, and in the excessive use of water for the crops grown.

Water-use efficiency under the existing projects in India is estimated to be as low as 40% (Navalawala 1994). According to one study, experiments carried out on the actual losses in the Upper Ganga Canal revealed that, of the water entering the canal, as much as 44% gets lost in the canal itself, in distributaries and village watercourses. Farmers tended to waste 27% through excessive irrigation, and only 29% was actually used by the crops (Veeraiah and Madankumar 1994). In contrast, in the advanced systems of the west, as much as 60–70% of the water diverted in large surface systems is available for plant use (Repetto 1986).

This enormous wastage of water during conveyance and in the fields arises basically on account of the absence of incentives to conserve water. In the absence of financial accountability and operational autonomy, project authorities do not have any incentive to take water-conserving measures like the lining of canals for supplying water on a volumetric basis. Similarly, since water prices are low and unrelated to the quantity of water used, the farmers have no incentive to economise in the use of water. On the other hand, the prevailing price system provides an inducement to substitute cheap and abundant water for measures like leveling the fields and for weed control. In cases of improper leveling of fields, farmers are found to apply excess amounts of water to ensure that enough water reaches plants situated on high grounds. Farmers also resort to the submergence of rice fields to check weed growth and thus increase yields (Veeraiah and Madankumar 1994). These types of practices, induced as it were by the pricing structure of canal waters, often lead to waterlogging and salinity in canal commands. In the absence of large-scale investments in drainage, this then leads to vast areas either going out of cultivation or at least giving returns much below their potential. There are canal commands such as Sarda Sahayak in Uttar Pradesh where waterlogging and salinity has already affected more than one quarter of the command area (Joshi and Tyagi 1995).

Not only is water use excessive in the command areas of surface irrigation systems, crop yields are also only about half those achieved under private irrigation from tubewells (Dhawan 1995). This is basically attributable to the uncontrolled nature of water supplies in the surface irrigation systems, which could be remedied to a large extent if there were incentives at the project level for modernising the systems and spreading water to larger areas. Controlled irrigation would not only raise yields but would also facilitate extension of water thus saved to new areas. Apart from avoiding waterlogging and salinity, modernisation systems and incentives to economise water in field application would appear to result in at least doubling the output from the available water resources by raising yields as well as expanding area under irrigation.

Inequity

A disquieting consequence of under-pricing of surface water is the persistent pressure exerted by the farmers at the head reaches to water their fields so intensively as to leave the tail-enders with sparse supplies. Irregular and unpredictable supply also leads to inequities in the distribution of water between head and tail-enders. It has been reported that, in 46% of the irrigated area, under five major crops in the country, irrigation was hired from other households. As would be expected, those in canal areas are less dependent on the hired private sources than in non-canal areas. Nevertheless, the fact is that, even in canal areas, as much as 40% of irrigated area under five major crops is hired (the corresponding figure in non-canal areas being 49%). This phenomenon of hiring in irrigation services is even more prevalent in States such as Bihar (with 69% of the irrigated area hired), West Bengal (67%) and Uttar Pradesh (67%). In some States, the proportion of irrigated area in canal areas served by hired irrigation services is higher than that in non-canal areas. Such States include Gujarat, Haryana, Manipur and Arunachal Pradesh (NSS 1999). This tendency is largely responsible for the departure from the original concept of protective systems of irrigation. The intensive systems of water use which have come to be established particularly at the head reaches are a significant factor in causing the effective command areas of the system to become smaller than originally envisaged.

This excessive use of water at the head reaches has not only resulted in serious inequity, as between farmers at the head reaches and those at the tail end, but also considerably lowered the productivity per unit of water used. Moreover, this is one of the major reasons why the irrigation potential utilised in canal commands is usually 15–20% less than the potential created. Moreover, only 26% of the villages reported as having a government canal in 1997–98. This reflects considerable inequity in the distribution of irrigation services and therefore of subsidies.

Decline in public investment [7]

Rapidly increasing subsidies on canal irrigation can also be said to have had a strong negative impact on public-sector investments in agriculture. The genesis of this phenomenon is discussed below.

The mid-1960s saw a considerable increase in public investment in response to the need to achieve food self-sufficiency. The 1970s were characterised by the contribution of private investment in agriculture with the introduction of the profitable HYV technology and also because of its high complementarity with public investment. In the 1980s, however, the public sector's contribution to real gross capital formation in agriculture (including irrigation) declined (Rao et al. 1999). This was seen to be the outcome of the burgeoning subsidies in agriculture and the consequent erosion of funding for investment. The decline in the 1980s was at the rate of 1.73% per annum. This undesirable trend with respect to real gross capital formation in irrigation was observed even in richer States like Gujarat and Maharashtra, where over 50% of the irrigation potential of major and medium sources was yet to be exploited (Rao et al. 1999).

The outcome of this is that resources were spread thinly over a number of projects in the pipeline. As many as 500 major and medium irrigation projects at various stages of completion at the end of the 7th FYP entailed a spillover cost of Rs390 billion (Eighth Five Year Plan, 1992). At the beginning of the ninth FYP, there were over 340 spillover projects involving an outlay of more than Rs400 billion in the ninth FYP (GOI 1996). These time overruns contributed to the higher real cost per hectare of irrigation potential created.

7. This section draws on Rao et al. (1999).

Due to the decline in public investment and delay in completion of projects, the average annual addition to irrigated area by major and medium works declined sharply from the 1 million ha during 1974–80. During the eighth FYP (1992–97), the anticipated addition to potential created through major and medium irrigation projects was 2.09 million ha as against the target of 5.09 million ha (GOI, 1999 figures). The current trend suggests that, in order to exploit fully the remaining irrigation potential of 25 million hectares through major and medium schemes, it would take another 50 years. Even if no new projects were undertaken, the potential of ongoing projects would take two decades to realise. The declining public investment due to the financial burden inflicted by faulty pricing hinders achievement of food security and the exploitation of opportunities opened by trade. It may ultimately act as a brake on the growth of agriculture, particularly if private investment fails to fill the growing vacuum caused by falling public sector investment.

'The Vicious Circle' and the Need for Reform

The consequences of irrigation subsidies that have been delineated above form elements of a vicious circle (see Figure 3; World Bank 1999a). The water-pricing policy in India is such that it does not even cover the full cost of operation and maintenance of the irrigation systems, let alone the capital cost. This leads to severe financial pressure on the state since it has to absorb the subsidies. Because of the fiscal constraints of the irrigation service agency and the state, the budgetary allocation towards operation and maintenance of these systems is curtailed. Inadequate funding leads to physical deterioration of the irrigation system and affects water delivery and supply. The poor irrigation service is also caused by institutional constraints like the lack of incentive and accountability on the part of the monopoly government agency to assure quality supply. There is no link between irrigation quality provided, revenues generated and staff incentives. The irrigation departments are highly centralised and function with a top-down approach, failing to establish any linkages with the farmer-users. Furthermore, there is lack of coordination between departments dealing with agriculture and those involved in irrigation, within the irrigation department itself, and between agencies dealing with different types of irrigation, e.g. lift irrigation, canal projects or groundwater schemes. Lack of farmer involvement results in inappropriate design of irrigation systems, which also leads to poor irrigation service. Farmers as a result remain dissatisfied. Unreliable supply with iniquitous distribution of water leaves many disgruntled and unwilling to pay (higher) water rates. Indirectly, the poor irrigation service also affects the farmers' ability to pay, since inadequate irrigation (combined with inefficient water use technologies) results in low yields and incomes. Charging very low water fees results in severe inefficiency and wastage in water use. In the long run, environmental problems too are likely to have an adverse impact on yields and incomes. The unwillingness of farmers to pay more for irrigation services, coupled with the possible inability to do so, precludes any change in the water policy in terms of raising the water rates charged from irrigators. No policy-maker would want to risk such an undertaking. Nor is it fair to increase water rates without concomitant improvement in the quality of service. Improvements in quality in turn are constrained by funds and the inefficiency of the input irrigation agency. Thus, the vicious circle perpetuates. As far as the irrigation sector goes, we find ourselves in a catch-22 situation.

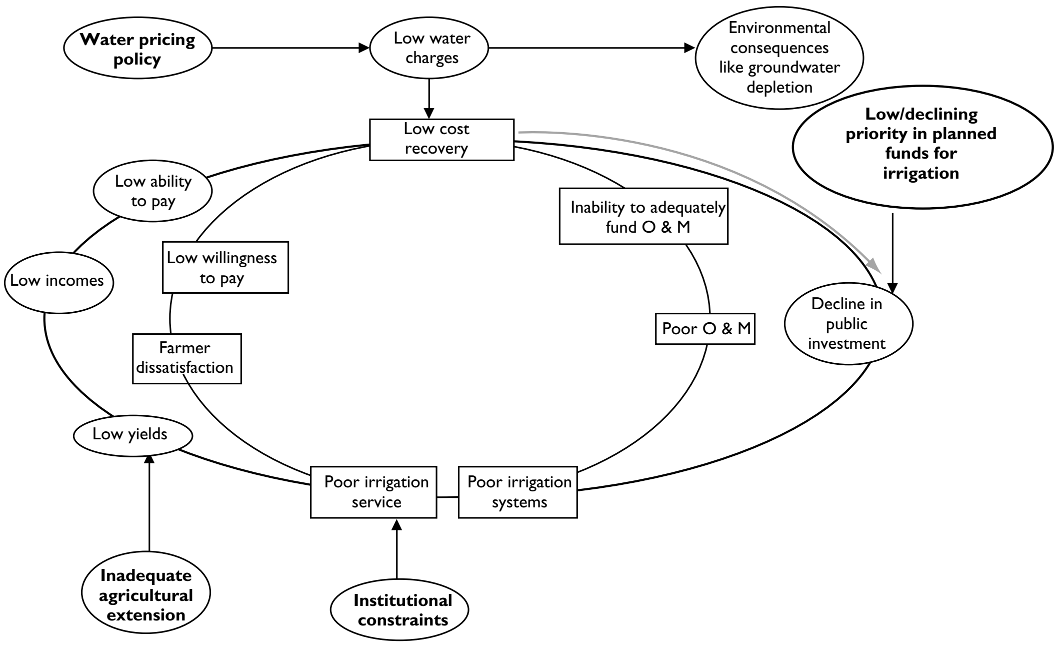


Figure 3. The vicious circle in Indian irrigation. The grey arrow indicates a weak link. Source: based on World Bank (1999a).

What is the Way Out?

If the vicious circle in Indian irrigation is to be turned into a virtuous circle it can be accomplished only through a multi-focused reform program. One of the elements of the vicious circle that should be targeted is price reform with the aim of ensuring that the irrigation agency is made financially self-sustaining and has the financial capability to provide an efficient irrigation service. Since price reform without improvement in quality of service is inconceivable, so price reform must be accompanied by fundamental changes in the institutional framework. Simultaneously, good agricultural practices and efficient water-use technologies must be promoted, so that excessive use and wastage of water are prevented. How can these be accomplished? Which way to go?

Price reform

Goals of water pricing

The guiding principles of water pricing from public sources are the following (Rao et al. 1999):

- resource generation for further investment through cost recovery;
- inducing efficient use of water;
- ensuring interregional and interpersonal equity; and
- protection of the environment through sustainable use of water resources.

These objectives are interrelated and generally reinforce each other. Rational pricing of water would generate sufficient resources for the maintenance of projects, and discourage wasteful use of water, thereby preventing environmental degradation in the form of waterlogging and salinity caused typically by excessive water use. It would also ensure equity between irrigated and non-irrigated regions as well as between farmers benefiting from irrigation and consumers at large. The relative importance of these objectives may, however, vary between sources of irrigation, and between projects within a single source. For example, although the failure to recover costs is a problem of equal magnitude in both major and minor irrigation projects and groundwater, the impact of under-pricing of electricity on water-use efficiency is more adverse in the case of the latter than the former.[8]

Principles of pricing

Theoretical and practical considerations in the pricing of canal waters are even more complex than in the case of power. This is chiefly because of the essential character of irrigation water as a commodity. There has been a debate as to whether it is a public good or a private good or somewhere in between. It is often regarded a private good with some characteristics of a public good (GOI 1992). The consensus of late is that it is a common pool resource with rivalry and non-excludability in consumption. Theory ordinarily suggests, as it does for power, that pricing should be based on the long run marginal cost (LRMC) principle to ensure efficiency and the maximisation of welfare in resource use. In the context of water for irrigation, the problem arises in defining LRMC, particularly whether it should include the capital cost of canal irrigation or only its operational and maintenance (O&M) expenses. If capital costs are to be included, then the LRMC principle presents several theoretical and practical problems. It has been argued, for example, that ensuring food security through the attainment of self-sufficiency in food grains has been the national goal generally, so that the production of food takes on the character of a merit good claiming priority in public investment. It is contended that it would not be justifiable to place the entire financial burden of achieving food security on the farmers. On a practical plane, it is pointed out that the actual costs incurred on publicly provided irrigation—whether capital or recurring—are invariably much higher than warranted, on account of the defective design of projects, time overruns, over-staffing and deficiencies in management. It would thus be unfair to place the financial burden arising out of such inefficiencies on the user-farmers. Thus, it is inconceivable, and justifiably so, to use the LRMC as a pricing principle when it includes the capital costs as well.

Normally, when one talks of marginal cost of canal irrigation it indicates basically the O&M expenses

8. The emergence of groundwater markets has, in the latter case, succeeded in efficient allocation of water resource between different uses. However, in the case of groundwater, underpricing of electricity has led to overdrawal of groundwater causing rapid environmental degradation. In this case, the inequity between resource-poor farmers and the large farmers (who have tube-wells) is grave, as also is the inter-temporal inequity (Rao et al. 1999).

alone (excluding capital costs). If one then adopts the marginal cost pricing rule, it raises an important question: how is one to recover the fixed capital costs of canal irrigation, which is often substantial? Theoretically, the charges for capital cost recovery can be separated out and recovered through some other instruments like land revenue or a 'levy', while using the marginal cost principle for pricing water.[9]

Pricing in practice

Pricing of canal waters is a State responsibility and hence tends to differ widely across States. In addition, prices also vary across crops within the same State and across the seasons for the same crop. Pricing can also differ across different regions or projects within the same State. Although there are some States, like the Punjab, which give free irrigation water from canals, in most States, pricing is based on crop area and the growing season. Since it is technically difficult and expensive to measure water supplies on a volumetric basis to millions of small cultivators, volumetric pricing seems to be impractical in the foreseeable future.

The debate on the principles underlying the pricing of irrigation water has for long veered round to the view that the farmers must pay at least the short-run marginal cost of providing water, comprising O&M charges and a small part of the interest on capital invested. Earlier, the fifth, sixth and the seventh finance commissions, in agreement with the Jakhade Committee, had recommended that pricing of canal irrigation water should recover 2.5% of the capital invested besides the working expenses. But given the poor financial performance of canal irrigation, the Eighth and the Ninth Commissions recommended the recovery of O&M expenses only. However, the tenth finance commission did reiterate the need to recover at least 1% of the capital cost besides the working expenses. The Vaidyanathan Committee (GOI 1992), which produced the last major report on this subject, had endorsed this view.[10]

In practice, however, the pricing of canal waters did not cover more than 20% of the O&M expenses in the mid-90s. It is well known that, over the years, the capacity of farmers to pay for higher irrigation charges has increased, due to the spread of HYV seeds, adoption of commercial and higher value crops, and higher productivity through better cropping operations. In the case of sugarcane in Maharashtra, for example, irrigation cost as a ratio of gross revenue from sugarcane farmers declined from 11.2% in 1968 to only 5.9% in 1995. Its share in net revenue decreased from 19.3% in 1968 to 9.7% in 1995. Similarly, in the case of paddy in the Punjab the ratio of irrigation cost to net revenue per hectare has fallen from 38% to 13–14%. This clearly shows that the farmers' ability to pay for irrigation charges has not declined over the past three decades or so. On the contrary, ability to pay seems to have substantially increased, and yet water fees have remained unchanged for decades. Besides, despite over-staffing, the actual expenditure on O&M per hectare of irrigated area is considerably below the accepted norms. Further, while the generally accepted principle is to collect, as water charges, between 25 to 40% of the additional net income generated per hectare on account of irrigation, only about 2–5% of such income is being collected as water rates.[10] The Vaidyanathan Committee on pricing of irrigation water (GOI 1992) also pointed out that in the case of major, medium and multipurpose irrigation projects for 1986–87, irrigation charges were less than 3% of the gross revenue on canal irrigated areas. In most of the States, this ratio was in the range 1–2.5%. The Irrigation Commission of 1972 had suggested that irrigation charges should form at least 5% of gross revenue for food crops and up to 12% in the case of cash crops. Several financial commissions and expert committees on the subject have repeatedly stressed the neglect of economic rationality in pricing canal waters and prophesied financial crisis, inefficient use of water and sub-optimal maintenance of the system as the outcomes. It therefore appears that, political resistance apart, at least a five-fold increase in the existing water rates may be necessary.

9. The history of irrigation financing in India since 1840 until the time of India's independence does in fact reveal these policy choices (Svendsen and Gulati 1999). However, over the years following independence, the relevance of these indirect sources for financing capital cost, land revenue, irrigation 'levy' etc. has eroded.

10. Of the gross receipts of Rs1.67 billion in 1986–87, direct and indirect irrigation charges constituted only Rs0.98 billion (59%). As against working expenses of Rs4.93 billion, direct and indirect irrigation charges work out to only 20%. See GOI (1992).

However, the Government does not seem to have taken any action on pricing revision, despite the recommendations of the Vaidyanathan Committee. In fact, prospects for change appear to be quite dim in the medium term. For example, Andhra Pradesh discussions with bureaucracy, farmers and political leaders reveal that Vaidyanathan's recommended phase-I pricing reforms (charging full O&M costs plus 1% of capital costs) might not be taken up for at least 5–10 years. The main challenge will be persuading farmers that such reforms will improve irrigation services. The goal for phase II reforms suggested by the Vaidyanathan Committee—full capital cost recovery—is not even being discussed at present.

The next obstacle is in the collection of water charges. Collections remain extremely poor, so much so that, in a State like Bihar, the cost of collection is more than the sum collected (Bhatia 1989). This reflects the urgency of the need for institutional reforms in such irrigation agencies/departments that are burdened with over-staffing problems. There is also a widespread feeling of large-scale corruption in these agencies, the effects of which must not be imposed on the farmers who happen to be consumers of their canal waters. The corruption and high costs of these agencies result from their monopolistic status, typically top-down bureaucratic structures and resulting lack of accountability to the consumers of their products. Under such a situation, prices of canal waters for irrigation alone will not solve the problem.

Price reforms in Indian irrigation, if they were so simple, would have been carried out long ago. The fact that the subsidy situation has worsened over time should compel us to recognise that the situation is not very simple. It is intertwined as much with the state and the nature of politics as it suffers from a lack of understanding of who is being subsidised and by how much. As a result, the suggested approach of reforming the regime of subsidies is often divorced from reality, and therefore, remains stalled.

Institutional reform

Why institutional reform?

In the context of irrigation subsidy reform, the preceding section raises two main points, particularly in the context of canal irrigation. First, the inefficiency of current operations, due to the monopolistic position of the state with regard to water, may mean that the costs of irrigation services are higher than they should be. Second, a higher willingness to pay is related to access to better quality services. As the consumer pays more, he/she also expects qualitative improvements in supply, in terms of quantity, reliability and timing of irrigation scheduling. It is for these reasons that price reforms must be accompanied by institutional reforms. Price reform is essential but is not by itself sufficient for a well-functioning irrigation system.

Recent efforts at institutional reform

A number of expert committees in India, starting with the Taxation Enquiry Commission in 1953 right up to the Committee on Pricing of Irrigation Water (GOI 1992), have expressed the desirability of improving the management of irrigation systems, to make them more responsive to the needs of farmers. However, experience shows that this will not succeed unless these systems are distanced from political interference and also de-bureaucratised. The recent debate on these issues among the experts all over the world has resulted in a remarkable consensus on the need to:

(a) make the project authorities financially accountable by according them operational autonomy;

(b) associate the user farmers with the decision-making process in the projects at various levels;

(c) entrust the water users associations with the tasks of managing the systems in their area of operation as well as collecting the water charges on the basis of some workable formula linking the rates with the quantity of water consumed; and

(d) allow the private sector to take up renovation and modernisation of parts or whole of the projects where feasible and to manage the systems by charging commercial rates (Rao and Gulati 1997).

The Vaidyanathan Committee (GOI 1992) recommended that, on the institutional front, user groups be involved in the management of the irrigation systems and that their role be gradually increased from management of minors to distributaries and then to main canal systems.

The preconditions to carrying out this recommendation are that there exist water user associations (WUAs) which can take delivery of water from irrigation authorities at wholesale level, and that there are measurement devices installed to determine the volume of water delivered at the distributory level. At present, neither of these pre-conditions are satisfied in most irrigation projects. As a result, the recommendations of the committee can be implemented only in the long run, with the gradual development of WUAs on the one hand and fixing measurement devices on the other.

The government has been quite slow in moving in that direction. Nevertheless, a beginning was made in the ninth FYP to set up a working group on participatory irrigation management (PIM), which recommended that farmers' involvement in the management of canal irrigation works should given high priority. Two thousand pilot projects are supposed to be taken up, which should cover 2–3% of total canal irrigated area in India. Gradually, this should be increased to bring 50% of irrigated area under PIM. However, implementation will require a lot of supporting changes in terms of defining water rights, and in setting the role and jurisdiction of the WUAs and the State irrigation departments, and mechanisms for dispute settlement. However, a beginning has been made in some States. The announcement of a one-time management subsidy to states for the forming of WUAs in the central government budget of 1999–2000 is another positive step in inducing institutional reform.

Efforts at forming WUAs in India have so far been small-scale isolated attempts. There were 4420 WUAs functioning in the early 1990s (before the 'big bang' in institutional reforms in Andhra Pradesh). The total area under their operation was, however, only 0.33% of the total irrigated area in the country (Rao et al. 1999). Several of the WUAs have been remarkably successful. For example, in Gujarat, under the Baldeva Medium Irrigation Project and Pigut Medium Irrigation Project, the WUAs are in charge of water management, setting of water fees and fee collection. Revenue collection in those projects was 100% in 1992–93, and had earlier increased by 57% in just one year in the Balveda MIP. In the Pigut scheme, cost recovery increased from 89% in 1989, its first year, to almost 100% in 1992–93. There also appears to be greater efficiency of water use, since the water used per unit of cultivated area declined by about 40% over this period (Navalawala 1998). The Mohini Pilot Project in Gujarat is another example where bulk water is sold on volumetric basis to the WUA by the irrigation agency, with the WUA being responsible for the collection of water charges from its members (Meinzen-Dick et al. 1994).

It has been observed that, in many of these institutions in India, the main focus of these associations was the management of the irrigation systems through the involvement of farmers. Cost recovery and other financial aspects were not the motivating factors for such organisations. It has been pointed out (Gulati et al. 1999) that this aspect may be of much greater importance to the future of irrigation systems, since as much as nine-tenths of finances in canal irrigation go into construction. Moreover, given the shrinking State funds and limited central government support, these WUGs should ideally devote equal attention to financial aspects of irrigation systems. This is true, especially because few of these WUAs have really emerged as robust institutions and most die out once external support is withdrawn. In this context, it is noteworthy that, so far, the impetus for irrigation management transfer in the different States in India has come from external agencies—Indian government policy and donor pressures (Brewer and Raju 1995). This may influence the type of WUA and the legal framework within which these institutions operate. What is really required, however, is a Statewide policy where the institutions are designed to suit the physical, technical and socio-political framework of the individual State. One way that these institutions could be sustained would be to make farmers co-owners of the systems, through say, equity shares, in a way that would allow them to participate in the management, design and construction of the irrigation systems. This would have to be backed by a strong legal framework.

It is only very recently that there has been a large-scale effort at institutional reform initiated by the States themselves. The most progressive State in this regard is Andhra Pradesh. Andhra Pradesh has taken a lead in passing an Act to transfer the management of irrigation systems to farmers' organisations. By 1999–2000, Andhra Pradesh alone had more than 10,000 WUAs. Beyond the distributory level, the WUAs manage distribution of water and collection of the fees due. There are early indications that the institutional reforms undertaken in Andhra Pradesh are successful (see Oblitas and Peter (1999) and Gulati and Naraynan (2000) for details on the Andhra Pradesh experience). Other States would do well to watch Andhra Pradesh and draw lessons from its experience. Many other States are indeed inching ahead on this line of action, most notably Rajasthan, Karnataka, and Haryana, besides Gujarat and Maharashtra, which already have an informal system of PIM. The donor agencies, such as the World Bank, are also insisting on the formation of farmers' groups and upward revision of canal irrigation water rates under their Water Resources Consolidation (WRC) projects in States like Tamil Nadu, Rajasthan and Haryana.

Direction of change: requisites for user involvement

Overall, it appears that the changes occurring are in the right direction. But the speed of change is slow and the outcome is uncertain. The degree of success will depend upon how far the user groups get interested in managing the canal networks, how much autonomy is granted to project authorities, and how much transparency is introduced in the management of funds. Learning from the experiments so far, conditions for the success of WUAs can be outlined (Kolavalli 1997). The results of a number of studies of Indian WUAs suggest that the major factors influencing the viability of WUAs are wide-ranging and comprehensive changes in the legal framework and policies, autonomy of the WUAs, a new accountability of the irrigation department to the WUAs and attitudinal changes in bureaucracy (Navalawala 1994; GOI 1997). With the Constitution (Seventy-Third) Amendment Act passed by the Indian Parliament, the strengthening of grass-roots institutions like the panchayati raj, it is possible to think of transferring management to local-level institutions. The case of West Bengal points to the efficacy of decentralised management of infrastructure such as irrigation (Sen 1993). Overall performance of WUAs in canal, lift and tank irrigation in the States of Gujarat, Maharashtra and Tamil Nadu has also been studied. The major pointers obtained from this and other studies[11] are given below:

- When faced with a legal fiat that water shall only be sold to groups of users, farmers are quick to come together.
- The existence of some flexibility in determining water charges helps, as allocation rules in successful WUAs often differ from region to region and depend on crops grown and corresponding irrigation schedules.
- It is sometimes found that external support for WUAs may be needed: this may be necessary to create capability. An NGO or the irrigation department may take this role for a limited period of time.
- It must be remembered that the creation of WUAs changes the strategic position that the irrigation department and its line agencies have had for a long time. Likely reactions on the part of this set of vested interests must be taken into account. Additionally, their experience needs to be tapped within the new institutional framework.

Although, certain factors have been identified as crucial to the success of WUAs, ultimately the key factor is designing institutions that are appropriate for a given socioeconomic, legal and political context. It is useful to note in this context that there exists a wide range of options in irrigation management systems, ranging from total farmer management to complete agency control (Subramaniam et al. 1995).[12] This emphasises that rather than an indiscriminate application of a successful model, there must be an effort to design and modify one that is most appropriate to the given context.

11. The requisites of robust WUAs have been studied in some detail based on the empirical evidence from several countries. See, for instance, Subramaniam et al. (1995).

12. Full agency control is often reported as the form of management, although in practice, it does usually involve some user representation, informal though it may be. Similarly, full WUA control is also rare in practice. 'Agency O&M, user input' is the more common form of irrigation management. Under shared management, agencies are responsible for O&M but not completely. WUAs share some O&M responsibilities while chiefly representing users. Many irrigation management transfers today are characterised by the WUAs subsuming the responsibilities of O&M while the state agencies continue to own and regulate the system. Another interaction system is where the WUA not only manages the system (that is have O&M responsibilities), but also owns the system. The state agencies have only a regulatory function here. What model is followed depends largely on the system level. At the river basin level, for instance, the state usually plays a dominant role and the users very little. For the main system level, again the state retains ownership and O&M responsibilities, although user representation may enable them to participate in decision-making. Shared management and WUA O&M is usually found at the system or distributory level. WUA ownership, agency regulation is often seen as the culmination of management transfer programs at the distributory level. Even here there are exceptions. In Bali, for instance, even the river basin level has little role for the state with temple priests allocating and distributing water in a traditional management framework. Similarly, in the Philippines and Nepal, there is WUA ownership of some main systems as well (Subramaniam et al. 1995).

In addition to the formation of WUAs, the ownership of canal networks starting with the distributories through the issue of water bonds must be given priority. Another policy is the establishment of tradeable water rights (Rosegrant and Binswanger 1994). This would require investment in irrigation technology—for conveyance, metering and diversion—and institutional improvement, and would result in more efficient water use.

It has also been suggested that individual irrigation systems be made financially autonomous, so that their income depends chiefly on the revenues that they collect for the irrigation service they provide. This would provide an incentive for stricter collection of revenue from users, apart from better service, which would facilitate better recovery. Although in terms of efficiency these corporations would be better performers than government departments, they are likely to be natural monopolies. It would therefore be essential to ensure transparency in their transactions and capital expenditures. The need to keep expenses transparent and under control would be greater if private sector participation were introduced. In this context, each State should have an independent regulatory commission—an Independent Regulatory Commission for Canal Irrigation (IRCCI)—like those for electricity supply, with decentralised agencies at user-group level. These organisations should have a fair representation of farmers, State government personnel, including irrigation bureaucracy, and independent well-known citizens of the State such as retired judges of high courts, or other such organisations. The idea is to bring the operations of this department somewhat closer to the people. This commission could streamline the process of awarding contracts to private parties for building structures, can make the information public, and ensure transparency in matters relating to expenditure and revenue. As stated earlier, there are reports of rampant corruption in irrigation departments, and unless means are devised to plug these leakages any policy drives will have only partial effects. This type of regulatory commission can also act as a dispute settlement body, in case differences arise between farmers and project authorities, or even within the farmer groups. In short its functions would be:

- to divorce pricing of canal waters from short sighted political considerations;
- to ensure transparency in contracts and check leakages;
- to involve user groups in awarding contracts relating to routine repairs and maintenance;
- to involve user groups in the collection of water charges on attractive commission basis;
- to act as arbiter or dispute settlement body between the users and the irrigation agency to ensure that the levy of water charges is conditional on actual delivery of water.

To sum up, institutional reforms must necessarily accompany price reform and must focus on the input supplying agencies and their modes of operation, and extend to the formation of new institutional mechanisms where considered necessary (Gulati and Moench 1997; Rao and Gulati 1997). Institutional reforms would provide the right environment for undertaking price reforms by depoliticising or disengaging the state from the management of irrigation systems. It should make individual irrigation systems financially autonomous in a way that their incomes are dependent on the revenue they collect from users of the service that they provide. Additionally, it would enable the linking of the payments for irrigation service with the quality of service offered by the agency in charge of the irrigation system, which has largely been absent so far. Unless this functional link between the revenue and service and performance (Gulati et al. 1995b) is established, the chances of successful reforms in this critical sector would remain very low.

Concluding Remarks

From the above analysis several facts come to the fore in the context of irrigation subsidies in India.

- The pricing of water is way below the level that any theory would suggest, be it demand-side pricing based on the marginal value product or supply-side pricing based on the long-run marginal cost.
- The collection of charges imposed is poor, making the actual receipts per unit of water even lower than their price levels.
- The quality of service provided by irrigation agencies is not satisfactory, so that the farmers often have to resort to hiring/buying water from fellow farmers. This alternative costs the farmer more than what he pays to the irrigation authori-

ties, indicating that he may have the ability to pay more for water actually delivered by irrigation agencies.

- However, the farmer is unwilling to pay higher charges since he does not anticipate a concomitant improvement in the quality of the service and higher charges for the same quality of service is strongly resisted.
- Raising canal water charges under the given institutional structure and quality of service become grounds for dispute between the bureaucracy and policy-makers on the one hand and farmers and their representatives on the other;
- One should also be aware of large inefficiencies in the input supplying agencies, the project authorities in case of canal irrigation.

The situation offers an opportunity for reform and this would surely be a win–win situation for the farmers as well as policy-makers. Reform can be achieved by ensuring that the quality of the irrigation service is linked to the price being charged. It also requires that the costing of this service is transparent and there is an effort to keep the cost down through innovative methods. The canal irrigation subsidy could be reduced without adversely affecting agricultural output. Farmers have the capacity to pay for higher irrigation charges, and many are willing to pay, but they need to be assured of better irrigation services and reduced leakage of irrigation funds. To achieve this, greater autonomy must be granted to the irrigation authority, farmers must be involved in management and decision-making, and an independent regulatory commission must be established to the system more transparent. With these institutional reforms, one hopes that canal irrigation in India will be able to overcome not only the issue of subsidy, recovering O&M expenses and 1% of cumulative capital expenditures at historical prices, but also be set on a path of sustainable higher efficiency, both physical and financial.

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Appendix 1. Development of irrigation potential (cumulative) through plan periods in millions hectares.

Plan	Major/medium irrigation		Minor irrigation		Total irrigation		Gross irrigated area[a]
	Pot.	Utl.	Pot.	Utl.	Pot.	Utl.	
Pre–Plan	9.7	9.7	12.9	12.9	22.6	22.6	22.56
First (1951–59)	12.2	10.98	14.06	14.06	26.26	25.04	25.64
Second (1951–61)-GW	14.33	13.05	14.73	14.73	29.06	27.78	27.98
Third (1961–66)	16.57	15.17			16.57		
Annual (1966–99)	18.1	16.75	19	19	37.1	35.75	35.48
Fourth 1969–74)	20.7	18.69	23.4	23.4	44.1	42.09	40.28
Fifth (1974–78)	24.72	21.16	27.3	27.3	52.02	48.46	46.08
Annual (1978–80)	26.61	22.65	30	30	56.61	52.65	49.21
Sixth (reappraised) (1980–85)	27.7	23.57	37.52	35.25	65.22	58.82	54.53
Seventh (1985–90)	29.92	25.47	46.61	43.12	76.53	68.59	61.85
Annual (1990–92)	30.74	26.32	50.35	46.54	81.09	72.86	65.097
Eighth (1992–97) (Target)	35.83	30.57	61.06	55.9	96.89	86.47	n.a

[a] anticipated
Note: Pot. = potential; Utl. = utilised.
Source: Water and Related Statistics, Central Water Commission, July 1998 (p. 117).

Appendix 1. (cont'd) Development of irrigation potential (cumulative) through plan periods in millions hectares.

Plan	Major/medium irrigation		Minor irrigation		Total irrigation		Gross irrigated area[a]
	Pot.	Utl.	Pot.	Utl.	Pot.	Utl.	
Annual (1992–93)	31.06	26.6	51.88	47.9	82.94	74.5	66.76
Annual (1993–94)	31.49	27.02	53.28	49.09	84.77	76.11	n.a
Annual (1994–95)	31.82	27.45	54.85	50.25	86.67	77.7	n.a
Annual[a] (1995–96)	32.2	27.74	56.51	51.55	88.71	79.29	n.a
Annual[a] (1996–97)	32.7	28.2	58.13	52.88	90.83	81.08	n.a

[a] anticipated
Note: Pot. = potential; Utl. = utilised.
Source: Water and Related Statistics, Central Water Commission, July 1998 (p. 117).

Issues in Irrigation and Water Management in Developing Countries with Special Reference to Institutions

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Abstract

Irrigation and water management are indispensable elements in increasing agricultural production and productivity in the developing countries. However, evaluation of the heavy investments made in irrigation by developing country governments and development banks reveals that the potential of these investments has not been realised. There is widespread recognition of the need to improve the performance of irrigation, particularly in the area of governance. The 'New Institutional Economics' has much to offer the study of institutional arrangements in water use. The basic concepts of the New Institutional Economics are summarised in this paper, and a review of the performance of irrigation institutions in a number of countries is presented. It is argued that heavy government involvement at the farm level, and bureaucratic interference, have been instrumental in the demise of effective institutional mechanisms in irrigation in many countries. It is clear that new thinking and practices are needed, particularly to develop institutions that are structurally suited for water management and protection at the local level.

IRRIGATION and water management are indispensable elements in increasing agricultural production and productivity in the developing countries. Agriculture is still a dominant sector of the gross domestic product in most countries. Increased food production to alleviate poverty, hunger and malnutrition and achieve food self-sufficiency is still a matter of priority. The developing countries have invested millions of dollars on irrigation development either through national governments or funds provided by donor agencies, in particular the World Bank and the Asian Development Bank. Evaluation of these heavy investments made on irrigation reveals that the potential of these investments has not been realised (Aluvihare and Kikuchi 1991; Vaidyanathan 1999). There is wide recognition of the need to improve the performance water management in particular. Irrigation water is essential to facilitate the adoption of improved crop varieties in areas with inadequate and uneven rainfall. The various policy reforms in many countries did not influence irrigation water use since water was provided by centrally managed public systems with minimal costs to the users because of subsidies (Rosegrant et al. 1995). Many adverse consequences have been observed, such as damage to the environment and exacerbation of income inequity etc. There is a need to evaluate these failures objectively before any further investments are undertaken.

Irrigation development is inextricably linked with several other factors such as technology, institutions, politics and development. Institutions for water control should not be viewed independently of other factors that define the institution itself. Factors such as technology, land tenure, farm size and rural credit availability influence the nature and the functioning of institutions. Irrigation in the developing countries is not simply a process of design engineering but very much a socioeconomic phenomenon. A holistic approach which delineates these relationships could provide a much richer interpretation of their relevance. The aim of this paper is to examine irrigation performance in developing countries over the last few decades in order understand the major issues that are important in maximising their potential.

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The specific objectives are to:

- examine basic concepts of institutions (property rights and common property) and how they affect government policy and irrigation performance;
- evaluate the future direction of technical change in agriculture and its relationship to irrigation development;
- review pricing policies for irrigation water; and
- make recommendations to achieve better performance in irrigation management.

Institutions in Irrigation Management

There is widespread agreement about the need to improve irrigation management to enhance efficiency of water use and sustainability of irrigated agriculture. Researchers indicate that institutional deficiencies are at the root of the water resource management problem. Innovative institutions and management structures are a precondition for tackling the problems of water management. The next section presents the main principles involved in the 'New Institutional Economics' (NIE) approach as a prelude to an empirical examination of the institutional experience in irrigation management in developing countries.

The New Institutional Economics approach

It has been long recognised that traditional neoclassical economics, by taking institutions as given or failing to recognise their relevance for the analysis of economic problems, has been unable to provide a satisfactory explanation for a wide range of conditions commonly found in developing countries. Neither general reference to market imperfections nor detailed analysis of their welfare consequences can help explain their pervasiveness and the considerable difficulties in removing them.

Institutions can be defined as a set of constraints that govern the behavioural relations among individuals and groups (Ruttan and Hayami 1984; North 1990). Organisations such as labour and credit markets (formal and informal) and rotational irrigation systems are all institutions because they embody rules and regulations that govern their operations (Ostrom 1990). Contracts implicit or explicit are institutions because they lay down rules that govern specific activities involving parties to the contract (Nabli and Nugent 1989).

The concepts of the New Institutional Economics can explain the absence or underdevelopment of markets such as interlinked credit, insurance, land tenancy and mixed cropping (Basu 1983; Yotopoulos and Floro 1992; Herath 1994, 1996; Herath and Jayasuriya 1996). The approach highlights the limitations of neoclassical economics and provides insights into how institutions are created. It is essentially microeconomic in nature and tries to explain the importance and determinants of institutions, their evolution over time, and also to evaluate their efficiency and distributional implications. Many issues such as transaction costs, collective action, organisation theory, limitations of the rationality of human behaviour and interest group formation have all coalesced into the New Institutional Economics (Williamson 1975, 1985).

Governments in developing countries can change the nature and role of transaction costs thereby increasing the potential of existing institutions. They differ only by virtue of their transactional and information costs, and critical evaluation of their nature and sources provides mechanisms whereby both can be employed to improve their performance. A clear understanding of institutions is necessary for the proper design of irrigation policy (Basu 1984). The New Institutional Economics has two broad general approaches, namely (a) the transactions and information costs, and (b) the collective action approaches. Both are relevant for the analysis of irrigation in developing countries. These are briefly reviewed below.

Transaction and information costs

There are several interrelated themes here, namely bounded rationality, opportunistic behaviour, property rights and asymmetric information. These factors can lead to innovations in institutional behaviour.

Bounded rationality and opportunism

Williamson (1985) combined bounded rationality and opportunistic behaviour in defining institutions. He defined institutions as transaction cost minimising arrangements. These can change with the nature of transaction costs. Decision-makers are not omniscient and can cope only with limited information at any given time and hence are boundedly rational. Bounded rationality can lead to opportunistic behaviour in dealing with others. This approach views institutions as transaction cost minimising arrangements. Institutions should evolve in order to economise on bounded rationality but minimise opportunistic behaviour.

Property rights approaches

The second theme is the property rights approach supported by Coase (1960) and Demsetz (1967) among others. The main proposition here is that, in the absence of transactions costs, assignment of private property rights will lead to efficient contractual outcomes. It posits that land rights evolve toward private property as the most efficient systems when land resources are scarce (Coase 1960; Demsetz 1967). This view states that emergence of new property rights occurs in response to the desires of the interacting person for adjustment to new benefit–cost possibilities. For example, when population pressure on land resources intensifies, competition for land can create externalities among users. Property rights develop to internalise externalities when the gains from internalisation are larger than the costs of internalisation (Demsetz 1967).

The gain is that the governance costs associated with collective regulation are avoided. Governance costs may increase due to opportunistic tendencies of users of the commons. Market penetration and the commercialisation of agricultural activities can occur under private property. Only private property rights will accomplish the necessary task of furthering the markets and economic efficiency. Property rights lower consultations and cooperation, and hence the transactions costs. Exclusive rights to the resource base provide sufficient incentives to encourage development and cultivation (North and Thomas 1977). However, private property rights do not provide any clues as to what happens when privatisation is too costly.

The survival of many indigenous irrigation organisations depends on their ability to evolve in response to environmental changes. Continuous technological and managerial innovations are necessary to sustain production. Ruttan and Hayami (1984) proposed the theory of induced institutional innovation. Herein lies the central role that technology can play. The key to the choice of property institutions is the transactions costs and the objectives of the decision group. Changes in factor endowments and product demand are important parameters in this thesis. They hypothesise that institutional innovations will be supplied if the expected return from the innovation exceeds the costs of innovation.

Asymmetric information

The third theme is associated with incomplete information and asymmetry in information. The problems of moral hazard and adverse selection are relevant for a large class of problems where asymmetry of information is present, such as in credit and insurance markets. Information asymmetry can lead to opportunistic behaviour creating inefficient solutions (Williamson 1985; Herath 1996).

Collective action approaches

Collective action approaches are concerned with the provision of public goods. They explain the success or failure of a given set of self-interested individuals undertaking collective action. Since public goods give rise to the free-rider problem, the theory of collective action is concerned with the explanation of optimising behaviour of individuals that leads to non-cooperation, as well as the conditions under which cooperation can be achieved. For one segment of this, namely the interest group and organisation, the theory of collective action is fairly well developed.

Resource and cooperating member characteristics

According to Olson (1982), the success of collective action is related to the homogeneity of the groups. Features such as the size of the group, its purpose and the similarity of group characteristics, their goals and incentives may foster cooperative behaviour. Attention is devoted to explaining the nature of group formation, size and purpose. The role of political entrepreneurship, poverty, low incomes and the importance of the resource for production explain why certain groups are formed. Group formation is difficult when the group is large and resource endowments are heterogeneous.

Olson (1982) suggested that collective action works better in smaller groups. Using a game theory approach to examine rotating irrigation associations, Weissing and Ostrom (1990) show that in equilibrium an increase in the number of irrigators is associated with an increase in water theft, other factors remaining constant. Also, for models of repeated games, cooperative strategies are more likely to succeed. Smaller groups may be useful, but economies of scale may be present for certain features such as lobbying (Bardhan 2000).

Common property scenarios

The common view. The private property theorists claim to address issues that seemingly were not capable of being solved through common property approaches. Proponents of privatisation argue that, since the externalities created by use of common property are not internalised, it leads to free riding and the degradation of the resource. Here the individuals benefit from the common property but the costs are not internalised and hence the group pays the full cost of the individuals behaviour (Demsetz 1967). Common property itself has been considered the source of failure of the commons in the so called 'tragedy of the commons' (Hardin 1968). Policy prescriptions that emanate from this scenario are either the imposition of private property rights or external intervention to strictly enforce rules that reduce common ownership problems.

There are many situations where private property may not be appropriate. The costs of negotiations and enforcement may be high in private property rights. These costs can increase with the physical base of the resource, greater spread of the resource and lower density of the resource because the costs of delimiting and defending the resource will rise (Dasgupta 1993). For some resources such as the open sea and mobile fish stocks, division of the property into individual units is impractical. If variability of returns to resources is high across time and space, the need to insure against this variability may militate against private property rights (Baland and Platteau 1998). It is shown that, in the presence of economies of scale, common property will save on transactions costs.

According to Runge (1986), common properties have some in-built resilience and can sustain various pressures through evolution into certain other forms ensuring the sustainable use of the resource. Runge (1986) argues that the difference between common property and open access resources must be clearly understood. Common property is governed by property regimes, whereas open access resources are not. Property is a future benefit stream and there is no property in open access resources but only an opportunity to use something (Bromley 1992). Common property resources have clearly defined boundaries, owned and controlled by a clearly defined group. Here individual members have rights to use the resource based on rules and norms of appropriation and will exclude non-members from any claims to benefits from it (Bromley 1992). In common property, there is tacit or explicit cooperation by individual users according to sets of regulations specifying rights of joint use (Ciriacy-Wantrup and Bishop 1975). Many features of rural life in the developing countries, such as poverty, uncertainty and in equitable distribution of resources and wealth, can result in common traditional rules being accepted in preference to expensive and difficult to coordinate and implement private property rights approaches. Irrigation resources in the developing countries reflect common property characteristics, and are often regulated and managed by generally accepted community rules, regulations and sanctions.

Common property externalities, isolation paradox and assurance. Runge (1986) developed the common property argument as a 'prisoner's dilemma game', a simple game in which collective decisions produce outcomes harmful to the group as a whole without intervention by some higher authority. In this situation, the two prisoners have two options: either to cooperate or defect. An optimal solution may not emerge because each has sufficient incentive to defect whatever the other does. Rational decisions by both make them worse off. The non-cooperative pair is an inferior Nash equilibrium. This view of common property, with the underlying premise of dominant free rider behaviour, is often used to explain overgrazing, deforestation or over-use of irrigation water. The independence itself locks decision-makers into a tragedy of the commons. Each outcome is Pareto inferior, and even if an agreement is struck, dominance of individual strategies will make these agreements unstable. An outside agency may be able to enforce authority, but even it can be unstable.

Where there are no dominant strategies, alternative outcomes are possible, depending on the structure of mutual expectations and resulting patterns of strategic choice.

According to Runge (1986), the joint use of a common property is often not a separable decision. The decisions are made based upon the expected behaviour of others. Thus, externalities enter into the cost function of the other in a multiplicative manner. Separable cost functions give the same result as the prisoner's dilemma game. However, if externality costs are not separable, then conflict is usually the exception rather than the rule. This is known as an assurance game, which is a two person cooperative game that does not a lead to conflict. Agreements are made in which neither party has an incentive to defect.

The possibility set for each player expands under common property because the gain possible from cooperative rules provides 'assurance'. The assurance problem provides a formal way to look at interdependence and non-separable externalities. By providing security of expectation, or assurance, reliable response to the uncertainty of social and economic interaction will occur (Ray and Williams 1999).

The interdependence is defined by practical rules, and there are endogenous authority systems that sanction rights and enforce rules. The authority systems and the cooperative ethic provide the common property users with assurance about the expected behaviour of other users, enable coordination and minimise free riding (Runge 1981, 1984, 1986; Oakerson 1992). These mechanisms encourage individual members to cooperate towards a group strategy. If they pursue an individual strategy, rules can be used to arrest such tendencies. The institution rules provide certainty about the expected actions of others. In the real world, the assurance problem comes under pressure and can break down due to commercialisation, changing perceptions, heterogeneity of the community, and nationalisation and public administration of the common property.

Role of social capital in New Institutional Economics

Neoclassical models of rational choice explain human behaviour using internal economic and cost–benefit calculations. These models do not adequately consider the importance of social capital. However, social relationships are a resource that can be used to increase human wellbeing. In addition, social relationships can have positive social externalities within a society as a whole. The complex social relationships that include social norms, cultural values and institutions are collectively referred to as 'social capital' (Woolcock 1998; Rudd 2000).

Social capital has been defined in several other ways. North (1990) considers social capital to be institutions that lower transactions costs and 'trust' as an attitude or habit of mind (Fukuyama 1995). Putnam (1993) defines social capital as those features of social life that enable participants to act together more effectively to pursue shared objectives. Like other forms of capital it is productive, but differs in that it is self-reinforcing and cumulative. Its depletion is more likely to occur through under rather than over use (Putnam 1993). Social capital can lower transactions cost. In societies characterised by a high level of trust and strong civic and social norms, transactions costs tend to be lower. Social capital, in comparison to physical capital, generates mutually-beneficial collective action (Uphoff and Wijayaratna 2000). There is therefore a greater range of market transactions in outputs, credit, land and labour (Fukuyama 1995). There are stronger incentives to innovate, and to accumulate physical and human capital. There may be greater sharing of risks and the scope for cooperative action by local groups is expanded particularly in cases where excessive exploitation of assets would result from purely individualistic behaviour under open access to 'common resources' (Ostrom 1990).

Ecological economists place considerable importance on social capital to develop institutions to manage natural resources, because cooperation among the stakeholders is an imperative. The public good nature of, say, irrigation water, is such that if the market is to produce it, there will be under production due to individual self-interest. However, if common understanding develops among the individuals of a group sharing a public good, it implies that collective action will develop. Collective action is enhanced by trust and reciprocity. In the aggregate, increased returns are achieved via increased levels of generalised social trust and by institutionalising mechanisms of trust, reputation and reciprocity (North 1990; Putnam 1993; Fukuyama 1995).

Empirical evidence of the role of institutions and social capital on irrigation water management

There is a wealth of evidence supporting the usefulness of institutions that operate in ways discussed above in irrigation water management. Some of this is presented for several developing countries in this section.

India

India's freshwater lakes and streams have been used for irrigation through construction of thousands of village tanks and canals maintained by local communities. During colonial rule, the British collected revenues from village schemes. After independence, the revenue role of village tanks diminished, but government involvement to control the resource base led to take over of the tanks by the Minor Irrigation Department. Government involvement led to a collapse of some of the village irrigation systems due to problems such as siltation and poor maintenance (Shankari 1991). Elsewhere in India, private ownership or operation of surface and groundwater use for irrigation has generally replaced collective action. The result is substantial degradation of natural resources (Singh and Ballabh 1997).

Bardhan (2000) examined in detail cooperation in irrigation management in Tamil Nadu (South India) by empirically examining data from 48 irrigation communities in over six districts. The units examined in each village were either a tank or a branch of a canal with a command area of roughly 50 ha. Bardhan's (2000) work revealed that cooperative behaviour is positively related to duration of access to water, monitoring by guards, social homogeneity and smallness of the group. Cooperation is negatively related to inequality of land-holding and urban and market relationships. In the canal systems, which were under some form of bureaucratic management, there has been increased violation of water-sharing rules and hence resistance to cooperation. Bardhan (2000) also found that the water-user associations in canal irrigation set up by the bureaucracy ended up as fundraisers rather than efficient distributors of irrigation water.

Wade (1982) examined the irrigation bureaucracy in India and showed that irrigation engineers raise vast amounts of illicit revenue from the distribution of water and contracts, and redistribute part of this with their superior officers and politicians. He argues that the corruption system, which is centred on control of personal transfers, is an important supply-side reason for poor performance of canal irrigation.

Wade (1987) conducted detailed studies of irrigation in southern India. He found that special institutional arrangements, which include traditional customs and norms and other social conventions, could induce cooperative behaviour in irrigation water management and minimise problems related to collective action.

Government sponsored rotational irrigation is practised in the canals of the Deccan Plateau in Maharastra. The canals are run on an 'off-and-on' basis with a subset of watercourses full at any given time. In a normal year, the irrigation department will provide up to 15 irrigations with a dry interval of 14–21 days between them. For the Sananeri tank in India, allocation rules are relaxed at times of water abundance. It is a large bureaucratic system and a government-sponsored water users association oversees water appropriation. In the dry season, water distributors allocate irrigation water, which will be stopped if the water available is inadequate for the entire area. This shows that simply turning off and on of irrigation water is not adequate for water management. A more socially-responsive rotational irrigation system could have minimised the deficiencies experienced.

The case of Western Rajasthan in India dramatically illustrates the adverse consequences of privatisation and agricultural expansion through groundwater irrigation and large-scale canal and well irrigation. The arid rangelands have continuously diminished both in per capita and absolute terms. Land reform through privatisation and nationalisation attempted to establish private property rights, to the exclusion of an enabling environment for the evolution of new common property management institutions (Shanmugaratnam 1996). These policy interventions altered land-use and tenurial systems and traditional institutions of common property management, with serious environmental consequences. Traditional pastoral activities were marginalised and serious resource degradation occurred in both private property and common pool resources. Jodha (1990) argues that loss of common property management systems has been a critical factor in the degradation of natural resources. Jodha (1990) found that, in 82 villages he studied, when compared with the 1950s, only 10% of the villages had any regulated grazing provided by watchmen. None of these levied grazing taxes or had any sanctions been imposed upon those who violated local regulations. Only 16% were obliged to maintain and repair common resources.

Sri Lanka

There are documented cases where collective choice arrangements in large irrigation schemes in Sri Lanka outperformed agency-based management. The Gal Oya Project, one of the earliest irrigation settlement schemes in Sri Lanka, is an outstanding irrigation scheme in this regard. The institutional organisers introduced local farmer organisations in 1980, with considerable success. The farmers assisted by the Agrarian Research and Training Research Institute (ARTI) and Cornell University (Uphoff 1985; Ostrom 1990) created the organisational roles and rules.

There was significant improvement in the efficiency of rice production after this arrangement. Despite pessimism by technical personnel, millions of dollars worth of rice was produced during the dry season when water is considered inadequate to grow this crop (Uphoff and Wijayaratna 2000). The institutional arrangements introduced were able to distribute very limited water so sparingly yet effectively that a better than a normal crop was obtained with only a portion of the water supply considered necessary. This even surprised the irrigation engineers and is one of the most successful cases of mobilisation of social capital for irrigation management in Sri Lanka

The village irrigation schemes often referred to as minor tanks in Sri Lanka have a long tradition of user management (Herath et al. 1989). Most of these tanks are small and the command areas are often less than 200 ha. Water is available only in the wet season, and is used for paddy production. In the dry season, other crops that require less water such as potatoes, grams and subsidiary crops are grown. The small schemes have some redeeming features, namely that they have an inbuilt local decision-making systems, including rotational irrigation. Empirical studies of these schemes including tube-well irrigation in Sri Lanka show that smaller plots of paddy have greater productivity than the large farms and better adoption of new technology (Herath 1984; Herath and Silva 1988).

In most of the major tanks and diversion schemes, government involvement in water management is high. This reflects the growing complexity of projects, the larger resources required and greater expertise, and a higher level of political mediation of conflicts between sectoral and regional interests. Government involvement has resulted in problems similar to that of India with reports of abuse, corruption and theft of water.

Nepal

The Arnapurna irrigation scheme in Nepal was established to provide irrigation to 4100 ha to increase grain production. It has a 2 km canal with five branch canals. The district irrigation office (DIO) is responsible for water acquisition, delivery and distribution. There is one supervisor, three watchmen and three gate operators. There is inadequate canal maintenance due to delays in funding from the DIO. Farmers undertake emergency management. Allocation of water is based upon farm size. In general, rotational irrigation is practised but this is done even when water is sufficient in the branch canals. The head–tail problem is conspicuous here and the downstream farmers often receive less water, causing conflicts, and theft of water is very common in this scheme. The water-users association formed in 1992 has the responsibility to distribute properly and mobilise farmers' support for maintenance and repairs. A study using logit analysis has shown that water availability on time is the single most important factor determining satisfaction among farmers. Other important factors are fertiliser availability, land size, farmers' participation in activities, and location of farmland along the canal (Maskey and Wan 1996).

Japan and China

In post-war Japan, planning and management of irrigation works have been again the responsibility of the farmer associations in the respective areas more than the case in, say, India. Governments undertake design and construction of the barrages and canals only where it serves more than one land improvement district. In other cases, government assistance is limited to technical advice and partial financial assistance. China and Japan also have had a long period of sustained irrigation development through local efforts, requiring the beneficiaries to contribute labour and materials (Vaidyanathan 1999). In China and Japan, river diversions and ponds serve most schemes. The Japanese schemes are small but numerous. The average system serves a command area of about 250 ha, the largest being about 20,000 ha. Collective management appears to work well, and irrigators themselves have adopted watershed-based management. With increasing population, the traditional systems evolved into increasingly complex but precisely defined rules. Some of the rules of the irrigation associations were adopted at national level (Wade 1995).

Philippines

The government's national irrigation program in the Philippines organised farmers into groups and compared performance with those farming alone. Farmers in irrigation groups achieved a 19% increase in rice yield, contributed more to system costs and maintenance, and were more likely to see their suggestions incorporated into irrigation design. The evolution of institutions due to technological change was empirically tested for the Philippines by Ruttan and Hayami (1984). They tested their model against data on rice production under irrigation during the period 1956–76. In 1963, the Philippines' Government introduced new land reform to provide better incentives to farmers. Here, economic advantage drove a change in institutional arrangements. Institutional change governing the use of factors of production was induced when disequilibria between the marginal returns and the marginal costs of factors occurred as a result of changes of factor endowments and technical change. Institutional change was directed towards the establishment of a new equilibrium in factor markets.

Malaysia

The Muda irrigation scheme in Malaysia provides considerable evidence of the problems that emerged due to government policies on irrigation. The Muda irrigation scheme is the largest in Malaysia's six rice-growing areas. The irrigation area is approximately 96,000 ha. There was a mismatch of the outcomes of government policies with expectations. Conflicts and misunderstandings were common (Johnson 2000). Government policies did not achieve the productivity gains expected and water saving was not satisfactory. Tertiary intervention has increased the capacity of the farmers to unofficially control the distribution and supply of water and to engage in off-farm productive and unproductive activities. There has been significant overuse of water and a reduction in rice yields (Johnson 2000).

Haiti

White and Runge (1994) examined property rights in Haiti, where watershed management was driven through legislation. In particular, taxes, prohibitions, penalties and police action were used. Efforts to implement reforestation, soil conservation and watershed management have been unsuccessful. Monetary and commodity incentives were given to attract farmer participation. They ignored traditional knowledge and were indifferent to socio-cultural institutions and land-tenure conditions. The 'tragedy of the commons' had a firm foothold among Haiti's policy-makers who assumed that no cooperative systems would work. Environmental policies and development project strategies were driven by these assumptions.

Other countries

The uncertainty of access to inputs and technology, timing of supply of water and, more importantly, the behaviour of others in the group are important here. Even when the rules are clear, there can be violations by others. The costs and benefits to individuals arising from inadequate knowledge of the returns to investment caused by wide variations in individual circumstances are variable. These problems intensify when the irrigation scheme is large and water control extends beyond the individual communities, and when villages become integrated with the economy and polity of a larger territorial complexus. Fleuret (1985) refers to irrigation management in Kenya where cooperation is brought about by a common feeling of uncertainty with respect to the availability of resources. Cooperation in the management of common property resource systems operates this way for irrigation water in both homogeneous and heterogeneous communities. Potlanski and Adams (1998) conducted a very interesting study showing the relevance of institutional economics for the management of common property using Runge's (1981) hypothesis. They applied this model to indigenous irrigation institutions in Sonjo, Tanzania. They showed that the ruling politicians attempts to change the institutional arrangements of water control to serve better their own interests failed.

Technology Developments and Irrigation Expansion

Irrigation was the most important strategic factor in the green revolution in Asia and Latin America from the 1960s to the 1980s. Major investments on irrigation infrastructure were made in many countries to increase food production using the green revolution technology. In Punjab, agricultural productivity grew by around 6% annually for the next two decades. By the end of the 1980s, wheat and rice yields had trebled. Annual per capita income rose from $60 in 1980–81 to $440 in 1997–98, well above the national average. The dry zone of Sri Lanka recorded good increases in paddy production helped by irrigation from large and small irrigation schemes (Herath 1981). There were spectacular successes in the Philippines and Indonesia, and self- sufficiency in food was achieved in both these countries. These high productivities of the early high-yielding varieties (HYVs) of rice preserved the economic potential of irrigation in spite of its expensive nature (Aluvihare and Kikuchi 1991).

However, the prospects for continued large gains from new HYVs in the future are in doubt. Byerlee and Traxler (1995) examined the role of the national and international wheat improvement program in the post green revolution period. They found that type one technical change benefits have been nearly exhausted. It is widely believed that, unlike the earlier green revolution, the second green revolution is based on type two technical changes, where the increases in yield are not as dramatic. It may not have 'miracle rice' as a strategy: growth in productivity will be small and expensive investments such as new irrigation infrastructure will not be profitable compared with the green revolution period (Ali 1995).

The declining budgets, and expensive nature of research, mean that the international agricultural research system will play only a modest role in the future compared with private research initiatives. It is therefore widely believed that the second green revolution based upon gene technology may also have adverse consequences. Firstly, since the private sector has spearheaded this research, research will be geared towards profit, research on crops such as rice and wheat, the so called 'poor man's crops' may not even be conducted. However, if new technologies are developed in some of these crops, they may be expensive, which again emphasises the need to improve agricultural productivity through inexpensive but efficient means. Management of existing irrigation resources will be more important and expensive new irrigation investment will be uneconomic.

Further, the international agricultural research system has not yet developed any concrete research initiatives to generate the knowledge needed to address environmental issues at the farmer level (Ruttan 2000). These possibilities have important implications for the future management of irrigation resources in developing countries.

Pricing of Irrigation Water

There is growing acceptance that the enormous amount of irrigation development that was made during the last 20–30 years in Asia and other developing countries has not been paying good dividends (Sampath 1992; Johnson 2000). Many empirical studies have revealed that the irrigation investments have not achieved the expected increases in productivity, water savings, equity in income distribution and satisfactory operation and maintenance of irrigation facilities (Small 1990; Johnson 2000). This is specially so in the schemes established and managed by governments.

Government involvement is considered essential for irrigation development because of the public good nature of water and the lack of clearly defined property rights for water resources. The other reasons for government involvement are economies of scale, the high cost of irrigation investments, lack of potential local investors, political visibility of large projects and a desire to have political control of an important resource. Governments also try to achieve social objectives, such as income distribution and food self-sufficiency through irrigation development and management.

Wrong pricing policies for irrigation water have been recognised as major deficiencies of irrigation systems throughout the developing world (Rosegrant et al. 1995). The lower than expected returns are mainly due to the inability to price irrigation water at its opportunity cost (Rosegrant et al. 1995). It is very rare to find the use of marginal cost pricing for irrigation in any developing country. Often a flat fee is levied and hence the marginal cost for water is zero and this can lead to overuse. Many governments shy away from imposing the full costs upon the users of irrigation. This is because the improvement in the economic status of backward regions and less privileged groups is an important political goal and governments are unwilling to charge market-based prices for water (Sampath 1992). Also, charges are resisted by farmers whose returns are not high and whose production is often geared towards meeting household consumption needs (Sampath 1992). As a result, the cost of irrigation water to farmers is extremely low, varying between 5% and 15% of the canals operating costs in many countries. The World Bank found that in 17 irrigation schemes it examined, less than 30% of the total costs were recovered through pricing or other fees (Sampath 1992).

However, mechanisms to implement pricing policies for irrigation water have been discussed. Transferable water rights have been considered as a way to create efficient water rights. These institutions are not widespread in the developing world. However, some cases can be found. Martin and Yoder (1983) compared two villages in Nepal: Thulo Kulo and Raj Kulo. The irrigators in Thuklo Kulo had transferable water rights. Farmers who want water can purchase water from other farmers. Water can go to the highest bidder. In Raj Kulo, water rights during the monsoon rice season are restricted to individuals who cultivate land in a certain part of the village. Here, water rights are tied to particular plots and hence not independently transferred. In general, the various social, physical, technological, economic and political characteristics will pose special problems in introducing fully market-based allocation of water. Pricing of water will remain a contentious issue in the foreseeable future.

Concluding Remarks

It is generally accepted that the problems associated with large-scale irrigation in most developing countries remain unresolved. The outcomes of investments rarely correspond to expectations. Productivity increases, savings of water, and better distribution and allocation of water are still major goals. Poor design, management and maintenance are major shortcomings. The adverse environmental consequences of heavy irrigation development are well documented. Expansion of irrigation has raised watertables, caused salinisation and soil erosion. Some lands have been rendered irreversibly unproductive. Overuse of groundwater has lowered groundwater levels and too many tube-wells have been drilled and groundwater is quickly becoming depleted. Government intervention has destabilised the capacity of rural communities to self-organise for collective regulation. It has also often led to imperfect enforcement of regulations or corruption, which has led in turn to regulated common properties being converted into open access resources. Full cost recovery is still a serious issue.

Irrigation management policy can benefit from some perspectives of the New Institutional Economics. This approach suggests that due consideration be given to traditional and indigenous organisations, and local systems of water management. The new approach should be based on participatory decision-making. The role of the government is to facilitate effective functioning of these institutions. Government can influence the outcome of institutional change through appropriate forms of intervention, such as legal support provided to cooperative associations and other formal and informal water-user associations.

The experience of the green revolution suggests a need for a broader research agenda for the international agricultural research system. It should move from a commodity orientation to enhance the agricultural resource base. Research should focus on the commodity as well as the resource base, such as irrigation, so that they reinforce each other and not lead to adverse impacts. Pricing policies and subsidies for water need re-evaluation in the light of the New Institutional Economics. Modern business approaches to manage traditional resources in developing countries supported by government subsidies can make common properties end up as open access resources. Pricing policies should be developed and implemented in collaboration with local organisations.

It is therefore clear that new thinking and practices are needed, particularly to develop institutions that are structurally suited for water management and protection at the local level. This usually means more than just revising old institutions and traditions. It means new forms of organisations, associations and platforms for common action in rural communities, and more appropriate forms of governmental interventions such as legal recognition and provision of property rights for local institutions and assistance in the development of social capital.

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Impact of Irrigation Management Transfer on the Performance of Irrigation Systems: a Review of Selected Asian Experiences

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Abstract

During the last two decades, transferring the responsibility for irrigation management from government agencies to farmer associations has been a dominant component of irrigation-sector policy in several Asian countries. This paper synthesises the most significant evidence available to date about the impacts of management transfer programs. The analysis is based primarily on the results of case studies conducted by the International Irrigation Management Institute (IWMI) in four south and south-east Asian countries: Sri Lanka, Nepal, India and Indonesia. Performance is assessed from the perspective of the financial viability of irrigation systems, the quality of irrigation operations and maintenance, the physical sustainability of irrigation infrastructure, and agricultural productivity per unit of land and water. Trends in key performance indicators before and after irrigation management transfer (IMT), and performance levels schemes with and without IMT are compared.

Results are mixed. Following transfer there has been a statistically significant reduction in government financing of the operations and maintenance of irrigation systems, but water-user associations are making only a modest contribution towards maintenance. This raises some concern about the longer-term sustainability of the irrigation schemes. More recent evidence suggests that high transaction costs implementing IMT programs have slowed the pace of the management reforms in Asia. The paper concludes by specifying some essential conditions that should prevail for IMT programs to succeed.

DURING the last two decades, countries with a sizeable irrigation sector have been transferring the management of irrigation systems from government agencies to water -user associations or other local non-governmental organisations. The program is being implemented under a variety of labels: management transfer, turnover, self-management , participatory irrigation management and so on. A common objective of the various programs is to curtail the role of government agencies in irrigation management and give farmers more control and responsibility for managing irrigation systems. In most instances, governments pursue management transfer programs to reduce their recurrent expenditures on irrigation, enhance agricultural productivity levels and stabilise deteriorating irrigation systems (Vermillion 1997).

Despite the widespread adoption of irrigation management transfer (IMT) programs, little information is available internationally about the impacts of the management reforms on the performance of irrigation schemes. A question often asked is: Are the irrigation schemes that were transferred to farmer management performing better than under state agency management? With a few exceptions most reports that attempt to address this question are qualitative and hard to validate. It is important that impacts of management reforms are carefully analysed and understood, not only to set the record straight, but also and crucially because of the significance of such analyses for policy decisions pertaining to the irrigation sector.

This paper synthesises the most significant evidence about the impacts of IMT programs. The analysis is based primarily on the findings of case studies

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conducted by the International Water Management Institute in Indonesia, the Indian State of Maharashtra, Nepal and Sri Lanka. The paper also draws on evidence about impacts of management transfer on irrigation performance from other case studies carried out in the region.

The paper begins with an overview of government policy on IMT in the selected countries. This is followed by an analysis of the impact of the management reforms on the irrigation performance in terms of impact on government's recurrent expenditures for irrigation, the quality of the irrigation service and the agricultural productivity levels.

An Overview of Irrigation Management Transfer Policies in Asia

In most of Asia, management transfer entails only a partial devolution of responsibilities. Governments tend to retain some control over operations and maintenance (O&M) plans and continue to contribute to the financing of O&M. In most cases governments also remain committed for future rehabilitation and modernisation of the transferred schemes. Typically, post-transfer management organisations tend to be water- user associations (WUA). The scope of responsibilities transferred to the WUAs, and the institutional elements under which transfers have been launched, have varied among countries. In Sri Lanka, Nepal and Indonesia the government policy envisioned that the management of all smaller schemes would be transferred to WUAs.[1] Larger schemes are usually under joint management, with WUAs in charge of sub-sections of schemes (distributary and field canals), while government agencies continue to manage headworks and the main canal system. With some exceptions (e.g. tubewells in Bangladesh and Pakistan, and pumps in Laos) turnover does not confer to the WUAs the ownership of the irrigation infrastructure and other assets.

The formation of WUAs is central to IMT programs throughout the region. In Indonesia, following the transfer, three types of WUAs have been developed:

- a single organisation whose members and jurisdictions fall entirely within a single village area;
- a federated organisation responsible for a scheme with its service areas located in more than one village. The federation is composed of WUAs representing each village in the service area; and
- WUAs in irrigation schemes which serve multiple villages but have not been federated. Under this arrangement, representatives of WUA of each village coordinate with each other to manage O&M (Frederiksen and Vissia 1998).

The WUAs are legal entities and are essentially single-purpose organisations concerned mainly with O&M of the irrigation facilities. They are vested with the authority to formulate O&M plans and budgets, set water fees and have the right to contract and raise funds (Vermillion et al. 2000). The government retains responsibility for major repairs and emergency maintenance in the transferred scheme. The ownership of the irrigation facilities rests with the government. Water rights are also vested with the government. Legal provision exists for licensing water use, but it is not applied to irrigation. Farmers are said to have first rights to water, based upon historical use.

In Nepal, the government retains ownership of the irrigation facilities, but vests the right to use the facilities to WUAs as part of the memorandum of understanding (MOU) on transfer (Frederiksen and Vissia 1998). The ownership of surface and groundwater is also vested with the government. The MOU does not contain statements about water rights.

The new irrigation policy adopted in 1996 provides detailed guidelines for fees for irrigation services and authorises WUAs registered with the government to collect fees to cover the cost of O&M of facilities for which they are responsible. In the jointly managed schemes, the rates are determined jointly by the Department of Irrigation (DOI) and the WUA. In these systems, the total fees collected are shared by the DOI and WUA in proportion to the facilities for which they are responsible. It is envisaged that in the schemes under the Irrigation Management Transfer Program (IMTP) the irrigation service fee would cover the full O&M costs.[2]

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1. Small systems in Sri Lanka are those with a command area of less than 80 ha. In Indonesia, schemes smaller than 500 ha were earmarked for management transfer. In Nepal, it involved schemes that were less than 500 ha in the hills and 2000 ha in the plains (terrai).

2. In reality, this is not the case. In the smaller schemes (e.g. Khageri and Panchakanya) irrigation fee contributions amounted to only about 25% the O&M cost in 1995–96. In the larger schemes the share was less than 5%.

In Sri Lanka, the main function of the WUAs, or farmer organisations (FOs) as they usually referred to, is to deal with irrigation matters, but statutory provisions permit FOs the right to formulate and implement agricultural programs for their area, market farm produce and distribute production inputs. When legally registered, FOs have the authority under the irrigation ordinance to formulate rules on maintenance, conservation, and management of irrigation infrastructure under their jurisdiction, to devise procedures for distributing water within the area under their command, and to impose and levy fees to recover the O&M costs (IIMI/HKARTI 1997).

The ownership of the irrigation facilities remains with the government. However, a policy statement issued by the government in 1988 states that it would enact legislation to transfer the ownership of the irrigation network to FOs when they are found ready to take on that responsibility. To date, there has been no such transfer of ownership of irrigation facilities. In Sri Lanka, all water bodies except those which are entirely within the boundaries of private property are considered as public water resources. Legislation exists for issuing permits for water use but it is not strictly enforced. Water use for irrigation is exempted from the permit provisions.

In 1984, the government introduced a cost-recovery program for O&M in the larger irrigation schemes through the imposition of irrigation service fees. Even in the initial years only about 50% of the targeted amount was recovered. Due to questions about the legality and also political pressure, the cost-recovery program was abandoned four years later. Although FOs are expected to incur the full costs of their O&M responsibilities, in many cases, the government continues to subsidise O&M by financing maintenance contracts let to FOs. However, FOs often mobilise additional labour and other resources for maintenance from their membership.

In India, IMT is being implemented under the broader framework of participatory irrigation management. Irrigation is a state matter and there are considerable variations in the institutional framework relating to participatory irrigation management between the various states. These range from cosmetic changes in Haryana, where farmer involvement is only below the outlet, to more comprehensive efforts in Maharashtra and Gujarat, where WUAs are vested with the responsibility of managing minor canal commands of 500 ha.[3] The most far-reaching irrigation management reform program is being implemented in Andhra Pradesh where the Andhra Pradesh Farmers Management of Irrigation System Act 1997 provides for the formation of WUAs in all surface irrigation systems in the state. The WUAs are vested with the responsibility of, among other things, operation and maintenance of the irrigation system, water distribution, conflict resolution, collection of water fees. The WUAs are also authorised to mobilise funds through bank loans, and to levy fees and taxes. The most significant feature of the Act is that officials of the Irrigation Department are made accountable to the WUAs.[4]

In almost all countries in the region where transfer programs are underway, neither the post-transfer management entities nor individual farmers have clear water rights (Vermillion 1997). Within this framework, the devolution of management responsibilities to water -user groups has moved forward over the years in several Asian countries with varying degrees of success.

Impacts of Irrigation Management Transfer

This section synthesises the available evidence about the performance of irrigation schemes that have benefited from IMT. The analysis is based primarily on case studies conducted by IWMI about the impacts of management transfer on the performance of irrigation schemes in India, Indonesia, Nepal and Sri Lanka.[5] Performance is measured from several perspectives: the cost to government and to farmers of operating and maintaining irrigation systems; the quality of the irrigation service; and agricultural productivity. The main aim of the analysis is to determine whether there have been noticeable

3. Detailed accounts of IMT polices in the different states of India are given in Brewer et al. (1999) and Raju et al. (2000).

4. An authoritative account of the irrigation management reforms in Andhra Pradesh and key provisions of the supporting legislation the Andhra Pradesh *Farmers Management of Irrigation System Act 1997* is given in Raymond Peter (2000a and 2000b).

5. The details of the respective case studies are given in: Samad and Vermillion (1999), Sri Lanka; Vermillion et al. (2000), Indonesia; Brewer et al. (1999b), India; Samad et al. (1999), Nepal.

changes in performance of the schemes after management transfer.

Financial performance

Aspects of financial performance that were assessed relate to the government's recurrent expenditures for irrigation and the cost of irrigation to farmers.

Impact on government expenditure

One of the main reasons governments promote transfer programs is to reduce the financial burden of irrigation management (Vermillion 1997). It is expected that, following transfer, the farming community would take on the responsibility to fully finance or share the cost of operating and maintaining irrigation systems. This proposition was tested in all four countries selected for the study.

In Sri Lanka, government expenditure on O&M was analysed for 50 schemes over a 10-year period—5 years before transfer and 5 years after. The schemes selected were categorised into four groups:

1. schemes that were rehabilitated and transferred (with IMT);
2. schemes that were transferred (with IMT) but not rehabilitated;
3. schemes that were rehabilitated but not transferred (without IMT); and
4. schemes without either of the two interventions (without rehabilitation, without IMT).

A piece-wise linear regression model was fitted to analyse trends in government expenditure over the two time periods: before IMT (1985–90) and the period after (1991–95).[6] The aim was to determine whether the O&M expenditures incurred by government showed a particular linear trend from 1985 up to 1990 the year of transfer, but followed a different trend thereafter.

The basic regression equation estimated was as follows:

$$Y_t = \beta_0 + \beta_1 T + \beta_2 (T - T^*) D1 + e \quad (1)$$

where: Y_t = O&M costs/ha incurred by government in year t.

T = time in years (1985.............1995).

T^* = threshold period (i.e. 1990, the year of transfer).

$D1$ = 1 if T>1990

0 if T<=1990.

e = random error.

β_0.........β_2 are parameters to be estimated.

Assuming $E(e)$ = 0, parameter β_1 gives the slope of the regression line or the trend during the pre-IMT period (1985–90) and ($\beta_1 + \beta_2$) the trend in the post-IMT period (1991–95). A test of the hypothesis that there is a change in the trend between the two periods is conducted by noting the statistical significance of the estimated differential slope coefficient β_2.

Table 1 gives the results of the regression analysis.

6. The regression model used and the details of the methodology are given in Samad and Vermillion (1999).

Table 1. Estimated regression coefficients for trends in government expenditure for O&M of irrigation facilities in Sri Lanka, 1985–95.

Variable description	Regression coefficients			
	Rehabilitated schemes		Unrehabilitated schemes	
	With IMT[a]	Without IMT	With IMT[a]	Without IMT
Constant (β_0)	87.04	80.11	86.80	96.72
Trend in government's O&M cost/ha in the pre-IMT period (β_1)	– 0.879 (–5.684)*	–0.794 (–4.269)*	–0.885 (–8.271)*	– 0.983 (–5.023)*
The change in trend in government's O&M costs in the post-IMT period (β_2)	0.424 (1.373)	–0.2867 (–0.761)	0.346 (1.603)	0.428 (1.078)
Adj. R^2	0.534	0.4439	0.487	0.390
F. stat	43.42*	52.18*	102.47*	37.265*

[a] IMT = irrigation management transfer.
Note: * = significant at the 10% level. Figures in parenthesis are *t* values.

The results indicate that there has been a statistically significant decline in government's recurrent costs for irrigation during the pre-IMT period (1985–90) across all categories of schemes, irrespective of whether IMT programs have been introduced or not. There is no change in the declining trend in the post IMT period (1991–95). The results do not fully support the contention that IMT leads to a reduction in government expenditure for O&M.

In India, data collected from the selected minor canals from two schemes (Mulla and Bhima) in Maharashtra, showed that there is no reduction in government expenditure on operations and maintenance in the transferred minor canals (Brewer et al. 1999). In fact, in one location (Mulla) the average annual amount spent by government during the period 1987–88 to 1995–96 was higher in the transferred minor canal than in the non-transferred canal. This is a result of the repair costs incurred by government in accordance with the transfer agreement (Brewer et al. 1999b).

In the Nepal case, empirical evidence from West Gandak indicates there has been a reduction in the government budget allocation for O&M after transfer. Similar observations were made in the case the Bhairahwa Lumbini Ground Water schemes which were transferred to WUAs (Samad et al. 1999).

Comparable data for government expenditures for O&M in Indonesia were not available.

Cost of irrigation to farmers

In Sri Lanka, irrigation water has traditionally been supplied free to farmers. Attempts made by government in the past to levy a fee from farmers were largely unsuccessful. The 'costs' of irrigation to farmers are primarily the contribution of voluntary labour for canal maintenance and in, some instances, payments made in kind to persons (Yaya Palaka) employed by the agency to oversee the distribution of irrigation water. With the introduction of participatory management, the government expected farmer organisations to recover the cost of O&M from farmers. In a survey carried out in two schemes (Nachchaduwa and Hakwatuna Oya) farmers were asked to compare irrigation costs after transfer with costs of irrigation before transfer. Three kinds of irrigation costs were assessed: cash payments, payments made in kind, and the number of person-days of family labour contributed for canal maintenance. About 90% of farmers in both schemes claimed that there was no cash fee on irrigation before turnover. After the transfer of O&M functions to FOs, some organisations charged a modest fee for canal maintenance. The survey results showed that only a minority of farmers paid the maintenance fee. In both schemes, the irrigation cost to farmers is primarily unpaid family labour contributions for canal maintenance and payments in kind to the person employed by the FO to distribute water. In both locations, well-defined procedures for cost recovery have not been established as yet. Data from the two schemes do not provide sufficient evidence to suggest an increase in the cost of irrigation to farmers following the introduction of participatory management.

In the two Indian schemes studied, farmers pay crop-area water rates set by the state, and some additional fees. Therefore, irrigation costs to farmers are not attributable to IMT. Data indicate that the cash cost of irrigation has increased. But as water fees are collected by WUAs, the indications are that transaction costs associated with the payment of water fees has decreased, thereby reducing the actual cost of irrigation to farmers (Brewer et al. 1999a).[7] More recent evidence from Andhra Pradesh indicates that, following management reforms, there has been a three-fold increase in water fees. In addition, farmers are liable to pay fees levied by the WUA (Raymond Peter 2000a). Field studies carried out in the state suggest that there is not much resistance from farmers to paying higher water charges as long as they have a dependable water supply (Jairath 1999). Moreover, even with the increased water rate, the cost of irrigation water amounted to only 5% of the cost of production.

In the small-scale irrigation systems in Indonesia, water charges paid to the village or water users associations are normally paid in kind (paddy) rather than in cash. A sample of farmers from the selected schemes was interviewed about their perception of changes in the costs related to irrigation before and after turnover. The percentage of farmers reporting no change in the amount of water fees paid in kind varied from 38 to 85%. In two schemes (Planditan and Cipanumbangan), 35% and 60%, respectively, reported an increase in the fee after turnover. Generally, farmers did not express concern about the reported increases or decreases being worrisome or too dramatic.

In the West Gandak scheme in Nepal, irrigation cash costs to farmers are higher in the transferred minors than that in the non-transferred minor. The unpaid labour contribution at IMT sites is, on average, not different from that in the non-IMT sites. In the groundwater schemes, pumping charges for irrigation in the IMT schemes are higher than that in the non-IMT schemes. The unpaid labour contribution in IMT schemes is lower than that in the non-IMT schemes because the data in non IMT sites include the labour contributed in rehabilitation works.

Quality of the irrigation service

A key assumption of IMT programs is that, as farmers have a vested interest in the irrigation service, involving them directly in irrigation management would lead to improvements in the quality of the service. This section examines whether the introduction of participatory irrigation management has resulted in an improvement in the quality of irrigation service. Changes in the quality of irrigation service were assessed in terms of farmer perceptions of adequacy, timeliness and fairness of water distribution, and the incidence of irrigation-related conflicts among farmers before and after transfer.

A survey carried out in two schemes in Sri Lanka showed that a majority of farmers in both schemes claimed that the water supply in both the wet and dry season was adequate before and after transfer. In one scheme (Nachchaduwa), about one-third of the farmers in the head-reach and about 25% of farmers in the middle and tail-end areas reported that the water supply had worsened after transfer. Farmers attributed the worsening of water supply to the poor quality of work done during rehabilitation before management transfer. The responses of a majority of farmers in both schemes were similar with regard to the timeliness of water supply, fairness of distribution and the frequency of conflicts over water distribution, namely that these had not changed significantly after transfer. What was negative or positive before, remained so afterwards.

At the two Indian study sites, IMT has been beneficial for water distribution. Farmers clearly believed that water distribution has improved following transfer and that they have greater access to water when needed. Farmers made these claims despite the fact that a quantitative assessment of the overall water supply showed little or no difference between the transferred and non-transferred minor canal systems.

In Nepal, in both the surface irrigation systems and the groundwater schemes, the conclusion is that the adequacy and timeliness of irrigation water is better in transferred minors. In both locations, a higher proportion of farmers in the transferred minors reported that water distribution is much fairer now than before. Farmers in the transferred minors face less difficulty in getting the assistance of WUAs.

7. Transaction costs are travel costs and the time involved in visiting the agency office to make the payment.

The responses of farmers at the Indonesian study sites gave a mixed picture of the impact of IMT on the quality of irrigation service. In three schemes, a majority of farmers interviewed reported no change in water adequacy after turnover, some farmers saying it was adequate both before and after turnover, and others claiming it was inadequate before and afterwards. In one scheme (Kaliduren), the majority of farmers reported an improvement in water adequacy after turnover. Farmer perceptions about the fairness of water distribution were more positive. A majority in all four systems perceived that water distribution was either fair before and after turnover or was unfair before turnover but had become fair afterwards. In all four systems, between 60 and 80% of farmers interviewed perceived that the frequency of water-related disputes among farmers in the system had decreased after turnover. Only a very small number of farmers in any of the systems reported a worse situation after turnover. Regarding timeliness of water deliveries, the majority of farmers reported no change. In one scheme (Kaliduren), 55% of farmers reported an improvement in the timeliness of water delivery after turnover. Another 40% reported satisfactory timeliness before and after turnover.

Maintenance of irrigation facilities

The outcomes of transfer on maintenance investment were assessed by detailed field inspection of the full length of main canals, a sample of distributary canals in each scheme and all structures along these canal reaches. Field inspections were carried out in the two schemes in Sri Lanka, in the selected minors in the two Indian schemes and the four systems selected for study in Indonesia. In the case of the Nepal, the impact of IMT on the maintenance was assessed in terms of farmer perceptions of the condition of canals before and after transfer.

Field inspections in the two schemes (Nachchaduwa and Hakwatuna Oya) in Sri Lanka where IMT programs had been implemented, showed that only 5% of all structures in both locations were dysfunctional. In both schemes more than 60% of the dysfunctional structures at the distributary level had been dysfunctional for less than one year. In one scheme, 72% had been in that state for less than 2 years, in the other location this was 94%. There were no indications of significant long-term deferral of maintenance by farmers in Hakwatuna Oya. However, in Nachchaduwa 5 of 18 dysfunctional structures (28%) had been dysfunctional for 3–4 years. Farmer perceptions of the quality of maintenance were more negative in Nachchaduwa than in Hakwatuna Oya. In Nachchaduwa, nearly 60% of all farmers interviewed felt that the functional condition of the canal system was worse after management transfer. This implies extensive farmer dissatisfaction with the rehabilitation, which was done without farmer participation. In Hakwatuna Oya, farmers were more evenly split in their views about whether the functional condition of canal infrastructure was better or worse after management transfer.

At the two Indian sites, the physical condition of the transferred canals was better than the non-transferred canals, the latter being found to have more defects. This is attributed to the fact that the maintenance needs are identified by the farmers who use the canals daily and also because WUAs handle only one canal they are able to put in more management attention (Brewer et al. 1999b).

Evidence from the Indonesian sites indicates that after turnover farmers have not begun to invest in the long-term maintenance of the irrigation systems. The conventional pattern of farmers deferring some maintenance costs until the government might return with external assistance for rehabilitation has apparently not been overcome by turnover. Water user association leaders interviewed in all four systems reported to researchers that they expected that the government would return within 5 years time to finance another rehabilitation of their system.

Agricultural productivity levels

The relationship between IMT and agricultural productivity levels is less direct than the other performance measures considered earlier. But, the ultimate test of any intervention in the irrigation sector is that it should lead to improvements in agricultural production. It can be argued that, with the implementation of IMT, the shift of primary responsibility for water distribution to WUAs leads to improvements in the quality of the irrigation service, resulting in improved cropping intensities, encouraging farmers to use more inputs due to greater confidence in the irrigation service which in turn would lead to higher yields.

Crop yields

In Sri Lanka, the trend in paddy yields in 50 schemes over a 10-year period 1985–95 (5 years before and 5 after) were analysed using regression equation (1) with paddy yield per hectare as the dependent variable. The analysis was done separately for rehabilitated and unrehabilitated schemes with and without IMT. Table 2 gives the results of the analysis.

The results indicate that, in the pre-IMT period, paddy yields in the rehabilitated schemes, irrespective of whether or not they had been transferred, showed a declining trend. In the post-IMT period, there is a statistically significant upward shift in paddy yields in the group showing the effects of both rehabilitation and management transfer. There were no significant changes in trend in the schemes that had been rehabilitated but not transferred and those that had been transferred but not rehabilitated. In the post-IMT period, paddy yields in the group without the two forms of intervention show a statistically significant declining trend when compared with the pre-IMT period. The conclusion that emerges from the analysis is that there has been a significant improvement in yield in the schemes that have undergone both management transfer and rehabilitation. Paddy yields in schemes with only one type of intervention, and those without any of the two forms of intervention, show a significant declining trend.

Evidence from the Indian case study relating to improvements in agricultural productivity is mixed. Results show that farmers in the transferred minor canal (Minor 7) in the Mulla scheme had realised improved crop yields. They had also increased the irrigated area and shifted to higher-value crops (sugar cane). In the non-transferred minor canal (Minor 6), on the other hand, there had been a fall in the irrigated area and no significant changes in yields or cropping pattern. In the Bhima scheme, there were no significant differences in crop yields between the transferred and non-transferred minors.

The evidence from the Nepali study sites is also mixed. Yields of wheat and paddy in the transferred Palhi minor have been increasing over the last 3 years and sugarcane is not grown at all. There are no significant differences in aggregate yields of major crops in transferred and non-transferred minors. In the Indonesian schemes too, there were no differences in the trends in paddy yield between transferred and the non-transferred schemes.

Table 2. Estimated regression coefficients explaining trends in paddy yield in the selected schemes, 1985–95.

Variable description	**Regression coefficients**			
	Rehabilitated schemes		**Unrehabilitated schemes**	
	With IMT[a]	**Without IMT**	**With IMT[a]**	**Without IMT**
Constant	12941	5163	– 1761.38	–3558.15
Trend in paddy yield in the pre-IMT period (β_1)	–98.79 (–2.875)*	–6.32 (–2.219)	61.14 (2.338)*	89.83 (3.088)*
The change in trend paddy yield in the post–IMT period (β_2)	245.54 (3.799)*	–0.70 (–0.219)	–52.09 (–1.06)	–93.66 (–1.728)*
Adj. R^2	0.11	0.01	0.04	0.08
F. stat	7.81*	0.124	5.18*	7.72*

[a] = irrigation management transfer.
Note: * = significant at the 10% level. Figures in parenthesis are *t* values.

Cropping intensities[8]

The regression model outlined earlier was used to analyse trends in cropping intensities in the four groups of irrigation schemes in Sri Lanka. The estimated regression coefficients are given in Table 3. The analysis indicates that there were no significant differences in the trends in cropping intensities in any of the four groups of schemes in the periods before and after transfer.

In the Indian schemes, cropping intensity had improved in the transferred minor canal in the Mulla command, whereas it had declined in the non-transferred minor canal. In the second location (Bhima) there were no changes in the cropping patterns in either the transferred or non-transferred minors.

Field studies conducted in two schemes (Cinangka II and Cipanumbangan) in Indonesia showed that there were no significant differences in cropping intensity before and after IMT (Vermillion et al. 2000). Similarly, in West Gandak in Nepal, which had been brought under joint farmer-agency management in the 1990, cropping intensity had been static from 1992–96 the period for which data are available (Samad et al. 1999).

8. Cropping intensity here is defined as the ratio of the actual area cultivated under irrigation and the irrigable area that was considered to be the design area.

Conclusions

For the last two decades, irrigation management transfer has been a major policy in most Asian countries. Although there is a vast literature on the subject, no clear paradigm has yet emerged about the impacts of the efforts made to date. This paper is an attempt to obtain insight into the impacts of IMT on the performance of irrigation schemes. The analysis suggests that there is not enough unequivocal evidence regarding the extent of change. The main change has been a gradual decline in government financing of O&M of irrigation systems. There are also indications that, at present, WUAs are making only a modest contribution towards maintenance. This raises concerns about the long-term sustainability of the irrigation systems in the absence of adequate investments to ensure that they remain functional. There is no discernible evidence of the impacts of IMT on system operations and agricultural production. Evidence relating to agricultural productivity is mixed. The Sri Lankan study does suggests that it is only where both management transfer and rehabilitation occurred that significant positive effects on agricultural productivity levels were observed. But a paucity of data limits our ability to make a compelling analysis and generalise about IMT impacts.

Table 3. Estimated regression coefficients explaining trends in cropping intensities in the selected schemes in Sri Lanka, 1985–95.

Variable description	**Regression coefficients**			
	Rehabilitated schemes		**Unrehabilitated schemes**	
	With IMT[a]	**Without IMT**	**With IMT**[a]	**Without IMT**
Constant	–34.16	242.63	372.87	–27.21
Trend in cropping intensities in the pre-IMT period (β_1)	1.797 (0.578)	–1.356 (0.551)	–2.49 (–1.158)	1.57 (0.496)
The change in trend in cropping intensities in the post-IMT period (β_2)	5.878 (0.937)	5.545 (1.133)	7.026 (1.645)	–0.375 (0.058)
Adj. R^2	0.11	0.01	0.01	0.01
F. stat	4.31	1.041	1.511	0.424

[a] = irrigation management transfer.
Figures in parenthesis are *t* values.

There is a clear need for a comprehensive and long-term monitoring of the impacts within the framework of IMT, requiring a collaborative effort involving the direct stakeholders, governments, international financing institutions, and local and international research organisations.

More systematic research methods need to be applied with enough commonality to permit conclusions about impacts and to specify policy and institutional conditions under which IMT programs could be expected to succeed or not. There are signs that IMT had lost the momentum of the early 1980s. One of the primary reasons, as identified by Easter (2001) in a recent article, is the high transaction cost of implementing an IMT program on an extensive scale. The more recent success stories are those which were financially supported by international donor agencies. Where external support is absent, the progress of implementing IMT has slowed. This should not discount the IMT as an appropriate institutional intervention for improving the performance of irrigation schemes. At the same time, one should not be evangelistic about the merits of reform, but rather discover ways to implement IMT programs in a more cost-effective way. Research is also required to develop appropriate institutional arrangements that are compatible with socioeconomic contexts, foster inter-sectoral linkages, safeguard the interests of the disadvantaged groups and provide effective accountability and incentives for management.

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Constraints on Enforcement of Water Policies: Selected Cases from South Asia

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Abstract

To be effective, water policies should acknowledge the implications of the interrelationship of capital, labour and technology, and address the trade-offs between the environmental imperatives and socioeconomic exigencies of consumers. Approaches to enforcement of water policies may be sanction-based or compliance based. This paper identifies cases in Pakistan and India in which disharmony and complexity of policies, largely due to policy-makers' oversight or unwillingness, resulted in poor enforcement. The paper also evaluates an alternative water pricing policy, crop-independent water prices for culturable command areas for irrigated areas in Pakistan.

WATER policies reflect two different societal needs: (1) protecting the condition of the water resource base, and (2) maximising returns for the use of the resource—water. To be effective, water policies should acknowledge the implications of the interrelationship of capital, labour and technology, and address the trade-offs between the environmental imperatives and socioeconomic exigencies of consumers. An example of this could be the goal considered by the New South Wales (NSW) Department of Land of Water Conservation in Australia to manage groundwater. It is defined as 'The groundwater regime, measured over a specified planning time frame that allows acceptable levels of stress and protects dependent economic, social, and environmental values'.

Water policies fall broadly into two categories, namely 'market based', and 'command control'. The former is based on the 'rational polluter' hypothesis, and the latter is used when economic instruments may be impractical. Approaches to enforcement of water policies may be sanction-based or compliance-based. Sanction-based approaches aim to enforce regulation by compulsion and coercion. Compliance-based approaches recognise that the detection of deviant activity is the first step towards prevention.

The objective of this paper is neither to discuss policies, which may fall cleanly into the 'boxes' defined above, nor to blame social evils such as rent seeking or corruption as the reasons for the lack of enforcement of water policies. Instead, this paper will identify cases where disharmony and complexity of policies, largely due to policy- makers' oversight or unwillingness, have resulted in poor enforcement.

Disharmony

Example 1: Disharmony between local practices and laws

During the 1970s and 1980s, large-scale deforestation coupled with mining and related activities in Rajasthan, led to a severe decline in groundwater levels. The Government of Rajasthan declared parts of the district as a 'dark zone'; an area where the groundwater table has receded below recoupable levels. During the late 1980s and early 1990s, with the assistance of Tarun Bharat Sangh, a volunteer organisation, the villagers have rehabilitated 'johads', local tanks to store rainwater, and recharge groundwater. It is estimated that approximately 2,500 johads had been rehabilitated over time. Rehabilita-

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tion of johads is providing water for drinking, domestic and irrigation purposes to the local community. Indirect benefits include an increase in biomass productivity, fodder availability, more time for childcare, and improved rural health.

Under the *Rajasthan Drainage Act of 1956*, 'Water resources standing collected either on private or public land (including groundwater) belong to the Government of Rajasthan'. Since the Johads were built mainly on village common land, the state irrigation department declared that these structures as illegal. A notice was served in 1987 under the *Drainage Act* by the irrigation department that all these local structures must be removed as they block the natural drainage. In this particular case, there is disharmony between the law and what is obviously a beneficial practice of water conservation.

Example 2: Disharmony between laws

The Indus Basin Irrigation System of Pakistan is the largest integrated irrigation network in the world, serving 16 million ha of contiguous cultivated land. Waters of the Indus River and its tributaries feed the system. The salient features of the system are three major storage reservoirs, namely Tarbela, Chasma and Mangla, 19 barrages, 12 inter-river link canals and 43 independent irrigation canal commands. The total length of the main canals alone is 58,000 km. Watercourses comprises another 1,621,000 km. Surface inflow into the system is estimated to be 144 million acre feet (MAF) (176 m ML).[1]

Approximately 106 MAF (130 m ML) is withdrawn by the 43 canal commands and delivered to farms. Actual delivery of irrigation water varies within the irrigation system depending on: (i) the official allocation per canal and distributary concerned; (ii) the type of distributary (perennial or non perennial); and (iii) the quality of operation and maintenance practices adopted at canal, distributary and water-course command level.

Irrigation is managed by provincial irrigation departments in these canal commands, in compliance with the *Canal and Drainage Act 1873*. Under the *Canal and Drainage Act*, almost the entire irrigation network has been entrusted to the provincial government through the officers of the irrigation and revenue departments, and judicial officers (Muhammad 1998). It entrusts the provincial government with the tasks of acquisition of water for use, fixing water rates, appointing canal officers/committees and framing rules. Operational functions are entrusted to the canal officers. The revenue administration helps the irrigation department to acquire land, determine compensation, collect water dues, and settle appeals against/revise the orders of canal officers regarding the levy of charges for wasting water/unauthorised use of water. The collector (deputy commissioner) plays the main role, with the commissioner and the board of revenue exercising some appellate/revisional authority. Thus, the entire irrigation administration is entrusted to the bureaucracy, with almost nothing in the hands of water users.

The feeling that the irrigation management in Pakistan is in a financial and management crises started to emerge during early 1980s. The policy-makers and the donors, particularly the World Bank, were equally frustrated with continuous failure of projects and increasing waterlogging and salinity, operational failures, declining revenue and falling agricultural yields. The discussions between the donors and the government agencies on reforms started immediately after the famous paper on issues and options was presented in 1994 (World Bank 1994). The comments were exchanged back and forth to agree on a common framework. Provincial governments agreed to promulgate enabling legislation to make the irrigation and drainage agencies autonomous and self-sufficient for financial functions, and to turn over the secondary system to the organised water users.

The provincial assemblies of the Punjab, Sindh, Baluchistan and the Northwest Frontier each passed the *Provincial Irrigation and Drainage Authority (PIDA) Act 1997*. Under this Act, the existing provincial irrigation departments would become irrigation and drainage authorities. Farmers would be organised to take over operation and maintenance of watercourses, minor canals and distributories. A new institution—the area water board—would be the intermediary between these two levels, receiving water from the provincial irrigation and drainage authorities and distributing it among the federated organisations of farmers. Farmers would be responsible for levying and collecting charges for irrigation and drainage services, with the proceeds divided among the provincial irrigation and drainage authorities, area water boards and farmer organisations to reflect costs at each level.

1. 1 acre foot = 1.23 ML.

While there is high-level commitment to a revised institutional framework, detailed rules and regulations remain to be finalised. Within the broad specifications of responsibilities contained in the new legislation, the details of roles, functions and organisational structures to be evolved in the process of the transformation of provincial irrigation departments into provincial irrigation and drainage authorities are neither fully defined nor universally accepted by the present agencies. The same applies to their relationships with the area water boards, and the area water boards relationships, in turn, with farmers' organisations. The definition of functions and structure for the area water boards seems to have been ignored and these are being treated as the older irrigation circles with new designations for the old staff. In addition, important additional relationships (for example, supply of water to towns and villages within area water board jurisdictions; disposal of drainage effluent and storm drainage from towns; control of groundwater exploitation; monitoring and enforcement of water quality/pollution control standards) remain to be clarified. This inhibits the formation of farmer organisations with the capacity to undertake major responsibilities, and strengthens the position of line agency personnel at field level, who have reason to resist some aspects of the proposed reforms.

The government and the donors agreed to pilot test the concepts of the reforms at canal command level in each province. Thus, there are four canal commands which are to be managed under the *PIDA Act*, but others are to be managed under the *Canal and Drainage Act*. This creates enormous disharmony between and within government agencies as to their present and future roles. The provincial irrigation and drainage authorities are treated by other provincial ministries as another layer of bureaucracy, despite the fact that all relevant ministries are represented within them.

The *PIDA Act* requires the farmers organisations to operate autonomously, and to ensure equity in water distribution, maintain the distributory, and assess and collect water charges. Since these tasks are the responsibility of the government bureaucracy under the *Canal Act 1873*, the farmers organisations are often denied permission to carry out their tasks by the existing bureaucracy. At times they are even accused of violating the *Canal Act.* Another disharmony is that, under the *PIDA Act*, part of the revenue collected should be provided to the farmers frganisations for their operation, which is contrary to the provision under the *Canal Act*.

In our view, during *PIDA Act* development there was insufficient review of existing legislation and the consequences of pilot testing in 4 of the 43 canal commands[2] leading to the current difficulties.

Complexity

Example 1: Water pricing policy in Pakistan

Before the promulgation of the first-ever irrigation and drainage law, the *Canal and Drainage Act 1873*, farmers used to pay in kind. The monetary charges were notified for different canal commands from 1891 onwards. Initially, the objective of water pricing policy was to recover operation and maintenance (O&M) as well as construction costs of the irrigation system. The crop-area-based water charges, prevalent in India and Pakistan, are quasi-volumetric charges, reflecting relative crop water requirements and the benefit farmers used to get from the crops. For example, the water charges for sugarcane and vegetables were the highest. After the partition of the Indian sub-continent in 1947, the water charges were levied for meeting only the O&M costs (Mohtadullah 1997).

The current water pricing (abiana) structure in Pakistan is based on crops grown and the area irrigated on a farm, i.e. crop-dependent water pricing for irrigated areas. Charges are designed to reflect the benefit derived as well as poverty issues, in that water-intensive crops and cash crops are generally charged at higher rates, though fodder and food grains are charged at lower rates as being important to the poor.

2. The *PIDA Act 1997* was passed in a hurry (in a single day) to meet the deadline imposed by a donor to avoid forfeiture of a loan. The PIDA concepts were not owned by the senior and middle level officers of the irrigation departments, who either perceived proposed reforms as an indictment of their performance, or as a threat to their jobs and position in society. In contrast, *the Water Management Act 2000* of the State of NSW, Australia, which replaced the *Water Act 1912*, was developed over 5 years. In December 1999, a white paper was prepared, which received over 800 submissions. The final bill placed in the Parliament in June 2000 addressed concerns raised during the consultation process.

The irrigation water pricing policy in Pakistan demonstrates how an inappropriate policy can jeopardise sectoral performance. The policy was aimed at ensuring transparency, equity, and efficiency to ensure cost recovery for the irrigation services. However, due to the complicated procedures of assessment, billing and collection, the policy has been extremely difficult to implement and enforce. One of the major reasons behind the financial non-sustainability of the irrigation sector has been the pricing policy's failure to cater to the financial needs of the infrastructure and its management. Despite spending one-third of the assessed revenue on assessment itself, the policy instruments yield a high degree of opaqueness, underestimation, inequity, and poor recovery.

The crop-area based water charges were initially designed by the colonial administration to keep a complete track of the detailed assessment done by the booking officials. The complicated system of record keeping was designed to introduce cross-checks at each stage to avoid malpractices. The booking clerk has to physically survey each and every piece of land and examine and record the crop grown and the health of the crop.

The provincial irrigation departments' assessors are supposed to visit each and every nook and cranny of the command areas, and record crops and their health by each plot of land with its reference number. A standard list of water rates for various crops and soaking irrigation is used to prepare the bill. The supervisor of the assessor is supposed to inspect 10% of the area as a cross-check. There are several forms and registers to be filled before the draft bill is prepared and issued to the farmer for inspection. The farmers have to fill in forms of complaint if the assessment is wrong, and crop failure, if reported, is exempted.

Since the task is too complicated and laborious, the assessor goes to the village headman and uses local knowledge to fill in the register of assessment, multiplies the rates and sends the final bills to the farmers. Thus, he himself has made the process short, but maintains the paper requirements.

If someone is unable to grow a crop for any reason, he is able to sell the much valued canal water at a much higher premium to a neighbouring farmer, without paying any tax to the state, as he has no crop on his field. Since allocation of water is fixed per unit of land, a farmer double or triple-cropping his area, has to pay more than those who cultivate only one or no crop. The lack of direct relationship between crop-based water charges and the use of water constrains the efficient use of water.

An Enforceable Water Pricing Policy: 'CIA for CCA'

Several important new features have complicated matters since the system was formulated more than a century ago: first, groundwater development has radically changed the availability and control of water. Second, the infrastructure has in many areas been 'modified'—either legally in the course of modernisation, or by default as poor maintenance has led to silting of canals and effective redistribution of water from tail ends to head ends, or through the direct intervention of farmers, which is a symptom of the third major change, namely the reduced level of discipline that government agencies are able to exert both internally over staff and externally over the farmers served by the irrigation system. Water charges are at present remitted to the government, and there are no direct link between funds collected and funds spent on operations and maintenance. A crop independent abiana (CIA) structure based on culturable command areas (CCA) of a farm—referred to as the 'CIA for CCA' structure—may eliminate these drawbacks.

The current reform in the irrigation sector provides an opportunity to assess the viability of the 'CIA for CCA' structure in distributaries, which are transferred to farmer organisations. The reorganisation of water resources management will see a three-tier structure in place: at the provincial level, the provincial irrigation and drainage authority will have general responsibility for operation and maintenance of the major infrastructure, with area water boards operating groups of distributaries, and farmer organisations operating at the distributary/minor/watercourse level.

Thus, while the distribution of water was once achieved automatically by the proportionality of the channels, with intervention only at major control points, in future there will be specified interfaces (provincial irrigation and drainage authority to area water board; and the area water board to farmer organisation) at which services will be defined and monitored, and clear responsibility within each agency's area for O&M.

Farmers organisations will have responsibility for collecting funds, part of which will be assigned for O&M of upstream works, and part for the O&M of the farmer organisation's area, although the government will retain a role in setting charges. Given these important changes to the system, and the recent changes in water resources development and delivery, a reassessment of the way in which water pricing (*abiana*) is assessed is timely. Studies carried out by the International Water Management Institute identify the following advantages of a CIA for CCA pricing structure.

1. The CIA for CCA structure will be easier to administer by the farmers organisations, which are responsible for assessing and collecting *abiana*. Under a CIA for CCA structure, there will be no opportunities for under-assessment.
2. The CIA for CCA structure will result in significant savings, by reducing costs associated with assessment of *abiana*. Currently, PRs300m is spent in the Punjab to assess *abiana*. This cost burden will be significantly reduced under a CIA for CCA structure.
3. Farmer organisations, area water boards and provincial irrigation and drainage authorities will have a clear idea about the future availability of funds, and this will improve their overall planning and management.
4. CIA for CCA structure will benefit 87% of the farmers, who hold small to medium-size farms.
5. The International Water Management Institute's studies clearly show that the groundwater used in most of the canal commands is annually recharged by surface waters. However, many farmers avoid paying for water, claiming that they rely on groundwater only without recognising that groundwater is recharged by surface water transported through the irrigation infrastructure. CIA for CCA structure will prevent such farmers avoiding water payments.
6. The CIA for CCA structure will force the farmers organisation executives to distribute the water equitably across the distributary, since all farmer members (those at the head end of the reach as well as those at the tail end of the reach) will be paying the same rate per unit of CCA. In the event that the farmers organisation executive fails to deliver water to the tail end, the tail end farmers could refuse payment of abiana, making it difficult to manage the organisation.
7. The CIA for CCA structure will have no significant impact on crop selection by farmers, because water costs to a farm are very small (less than 2% of gross farm income).
8. The CIA for CCA structure will encourage farmers to increase cropping intensity on farms by practising deficit irrigation. The current structure requires farmers to pay a fee for the area irrigated only, irrespective of amount of water applied to unit area. The CIA for CCA structure will increase productivity and reduce waterlogging and salinisation.
9. The CIA for CCA structure will encourage water trading among farmers, a step forward for bringing in market forces in the water sector.
10. Under a CIA for CCA structure, any change in overall costs to manage irrigation and drainage infrastructure can immediately be translated to a change in water pricing, without debate about season, crop type, or any other complicating issues.
11. Assuming that the level of *abiana* is set at canal command level (area water board), varying in relation to operations and maintenance of the canal command, any variation in operations and maintenance costs among canal commands would be transparently reflected in the charging structure.[3]

It is believed that CIA for CAA will encourage efficient use of land and water since it will leave the decision about crop choices with the farmers, based on fixed water supply. Besides, the administrative costs involved in assessment would decrease substantially. Levying the water charges based on command area will, nevertheless, need to reconsider the current allocation rules for double-cropped areas, additional supplies to orchards etc. as these areas will obviously use more water but will pay equivalent to single-cropped areas. There is also a strong assumption implicit in levying area-based water rates that the water availability is normal and constant temporally and spatially. This assumption does not hold in practice, as there are frequent variations in discharges received even within a day. Besides, there is usually inequity in distribution of water at and among distributaries.

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3. The Indus Basin Irrigation System (IBIS) is approximately 1200 km long. Therefore water transfer cost will be higher for canal commands at the end of IBIS — closer to the sea).

An Enforceable Groundwater Management Policy

In many freshwater aquifers in India and Pakistan, the groundwater levels are falling due to unrestricted pumping. Groundwater is a common property accessible to many users who individually benefit from personal use, but suffer who collectively when the resource is depleted. In developed countries, groundwater pumping is regulated by relating the rates of withdrawals to sustainable yields of the aquifers. Considering the number of groundwater wells in Pakistan and India, regulating withdrawal rates at individual pumps will not be feasible. Alternatively, groundwater levels may be monitored, and when the level drops below a critical level in a year, groundwater pumping may be banned in the subsequent year (Perry and Hassan 2000). Groundwater users may be compensated through government grants during the years when pumping is banned, but may be severely fined, if the ban is violated. This will require public agreements reached with farmers.

Conclusion

Disharmony and complexity are not the only reasons for poor enforcement of water policies. But these two relate to omissions made by policy-makers at a stage when a concept is transformed into a policy. A lack of consultation among key stakeholders is often the reason for a lack of ownership and commitment to policies developed. Feasibility of enforcing a policy is often ignored, but academic details and potential benefits from the resource are given undue significance.

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Integrated Water Resources Management for a Small Basin: Huai Yai Basin, North-eastern Thailand

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Abstract

The Huai Yai basin is located in Khon Kaen Province of north-eastern Thailand. The basin has a catchment area of about 280 km^2. The average annual rainfall is 1,016 mm and the average annual run-off 28.5 million m3. The basin's population is 86,087. A working committee on natural resources management in the basin was established in June 2000 as an outcome of a research project undertaken by the Water Resources and Environment Institute, Khon Kaen University.

The basin's working committee consists of representatives from the development agencies (72%) of membership), the local people (22%) and the university's researchers (6%). Since the number of basin committee members is quite large, this committee has been further divided into five subcommittees corresponding with water resources, forest resources, land resources, community development and professional promotion. So far, the water resources and forestry subcommittees have been the most active.

A geo-engineering information system has been initiated for the Huai Yai basin so that the basin's working committee can have access to a database to support resource management decisions. An integrated resources management computer model has also been developed. The computer model simulates the water system, the land-use system, the reservoir fishery system and the socioeconomic characteristics of the basin.

Since the project is only a year old, it is too early to claim any success. However, with continuous improvement of the methodology and tools the integrated water resources management modeling approach being used in this study might have wider application in other basins in Thailand.

NATURAL resources such as land, forests and water have, through human exploitation, been reduced to a critically degraded state in north-eastern Thailand, as they have in other regions and perhaps in other parts of the world. Governmental agencies involved in development activities have been trying to manage these resources with out-of-date approaches such as top down and centralised management. In the water resources development sector, there are about 38 agencies involved in development activities, with little coordination. There have been many cases of duplication of small water projects because of these numerous agencies. Water resource projects have been planned for development on a case-by-case basis instead of a basin-wide approach. Similarly, the management of water resources projects has been undertaken individually without looking at the whole basin. In order to improve this situation, there have been attempts to establish a national water law over the past 10 or more years. One important aspect of this law is to manage water resources using a basin-wide approach. Though the drafted law is still to go through several steps before becoming implemented, researchers in Thailand have been conducting research using a river basin management approach. The National Water Resources Committee Office under the Office of the Prime Minister has been studying the river basin water management approach in three large river basins in northern Thailand since 2000. A similar approach has been undertaken by the project described in this paper, but on a small basin since it is believed that the management of a small basin is easier to implement. The small basin approach also makes it easier to empower the local people to participate in the management process and thus ensure the sustainability of the outcomes.

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The Huai Yai Basin

Location

The Huai Yai basin is one small basin of the Chi basin which is one of 25 large river basins of Thailand. It is located in Khon Kaen province between the latitudes 16°17.0′ and 16°41.0′ north and longitudes 102°32.0′ to 102°51.0′ east ,as shown in Figure 1. The catchment area of the basin is about 280 km^2.

Topography

The northern side of the basin has a hilly terrain with an elevation of 400 m above mean sea level (amsl). The middle part of the basin is rolling terrain with an elevation of about 180–200 m amsl. The southern part of the basin is a plain with an elevation of about 150 m amsl.

Demography

The basin covers parts of two districts, namely the Muang district and the Ban Fang district. There are 6 sub-districts located wholly or partly in the basin, which are further divided into 57 villages. The population of the basin is 86,087.

Meteorology and hydrology

The climate of the basin is monsoonal, with three seasons. The hot season is from March to mid-May. The rainy season is from mid-May to October. The cool season is from November to February. The average annual temperature is about 26.4°C. The average annual relative humidity is 70.4%. The average annual rainfall is 1015 mm. The average annual run-off is about 28.5 million m^3.

Land resources

Table 1 and Figure 2 summarise land use in the basin.

The most important land resource problem is salinity. The total salt-affected area is about 88,000 rai (6.25 rai = 1 ha), with about 1570 rai being seriously salt affected (more than 50% of this area has surface traces of salt). Figure 3 show the distribution of salt-affected area in the basin.

Table 1. Land use in the Huai Yai basin.

Category	Area (rai)[a]	Percentage
Dwellings	2,552	1.5
Paddy	102,732	58.8
Field crops and fruit trees	40,148	23.0
Forest	27,564	15.8
Water	1,591	0.9
Total	174,586	100.0

[a] 6.25 rai = 1 hectare

Forest resources

The forest in the basin is a deciduous type that is mostly degraded. At present, only about 16% of the basin area is forested. Fortunately, there are two national forest areas in the basin with a total area of about 49,150 rai.

Water resources

There are about 16 small streams in the basin. Most streams have gentle slopes, and not all are perennial. There are 25 small natural lakes with a total capacity of about 1.7 million m^3. There are small, built reservoirs with a total storage capacity about 1.788 million m^3 with the largest reservoir accounting for 78% of the total storage capacity. There are about 32 small diversion weirs in the basin. Each diversion weir can benefit an area ranging from 100 to 500 rai depending on the weir's size and location. Moreover, there are about 5,000 small farm ponds, each with about 1,100 m3 capacity in the basin. These ponds are suitable water supply alternatives for small farmers to undertake farming activities in the area that the reservoir system and the weir system cannot service. They can also serve as supplemental water sources for the reservoir and the weir systems. Figure 4 shows the location of water resources in the basin.

Problems related to water resources include the widespread construction of small-scale water resources projects without consideration of the basin as a whole, and management of dams and weirs at the individual level without coordination with upstream and downstream projects. Water shortages are common in the dry season, and even in the wet season in El Niño years. Salinity is also a problem in the water in some areas.

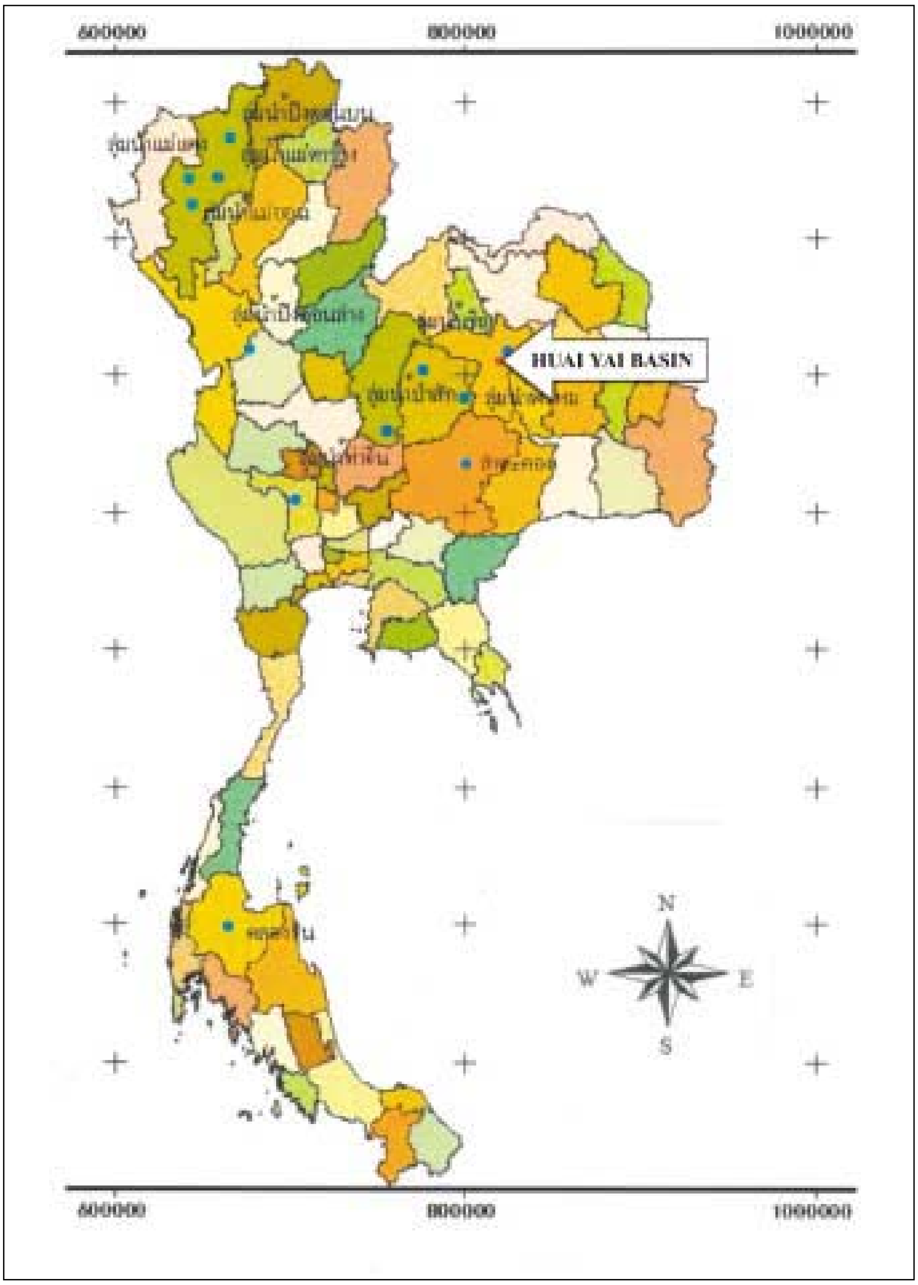

Figure 1. Location of the Huai Yai basin.

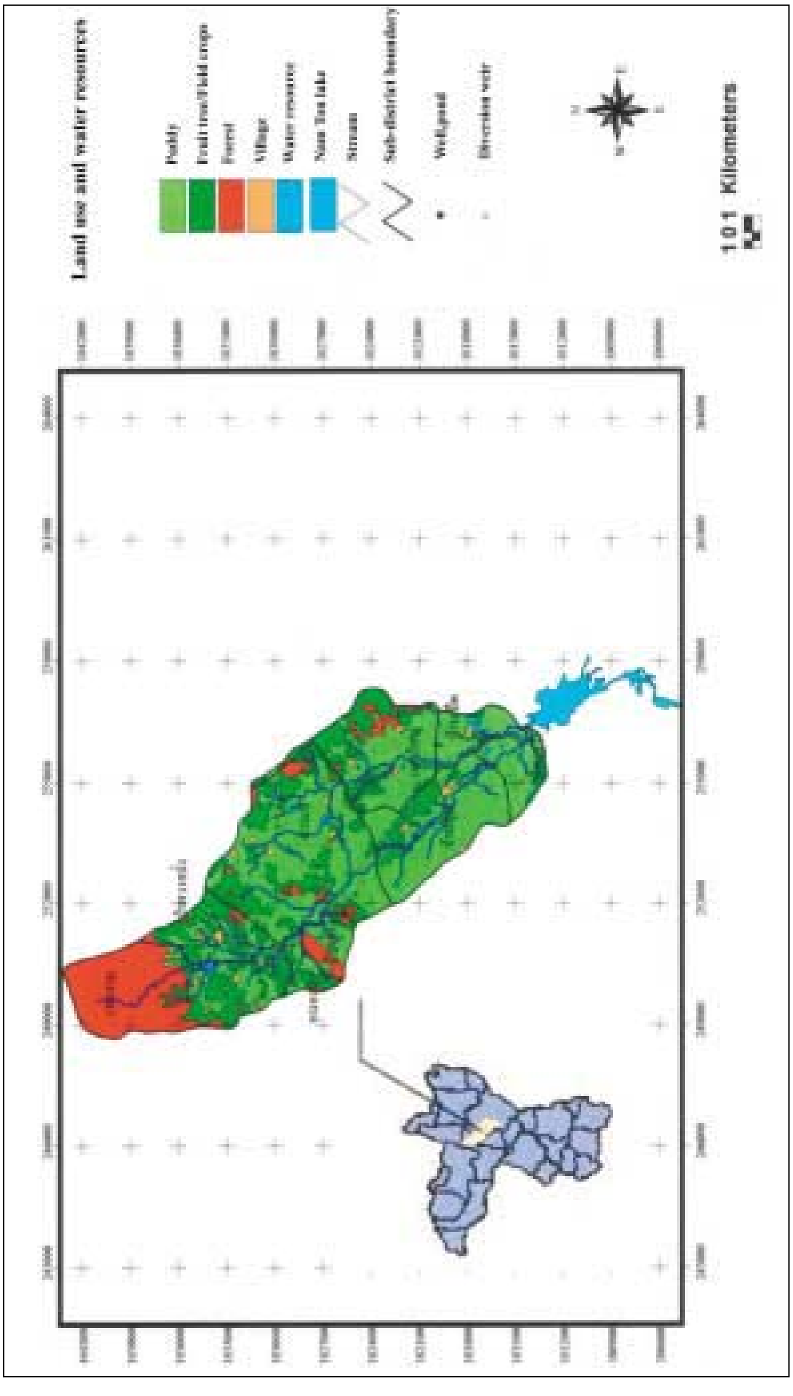

Figure 2. Land use and water resources of the Huai Yai basin.

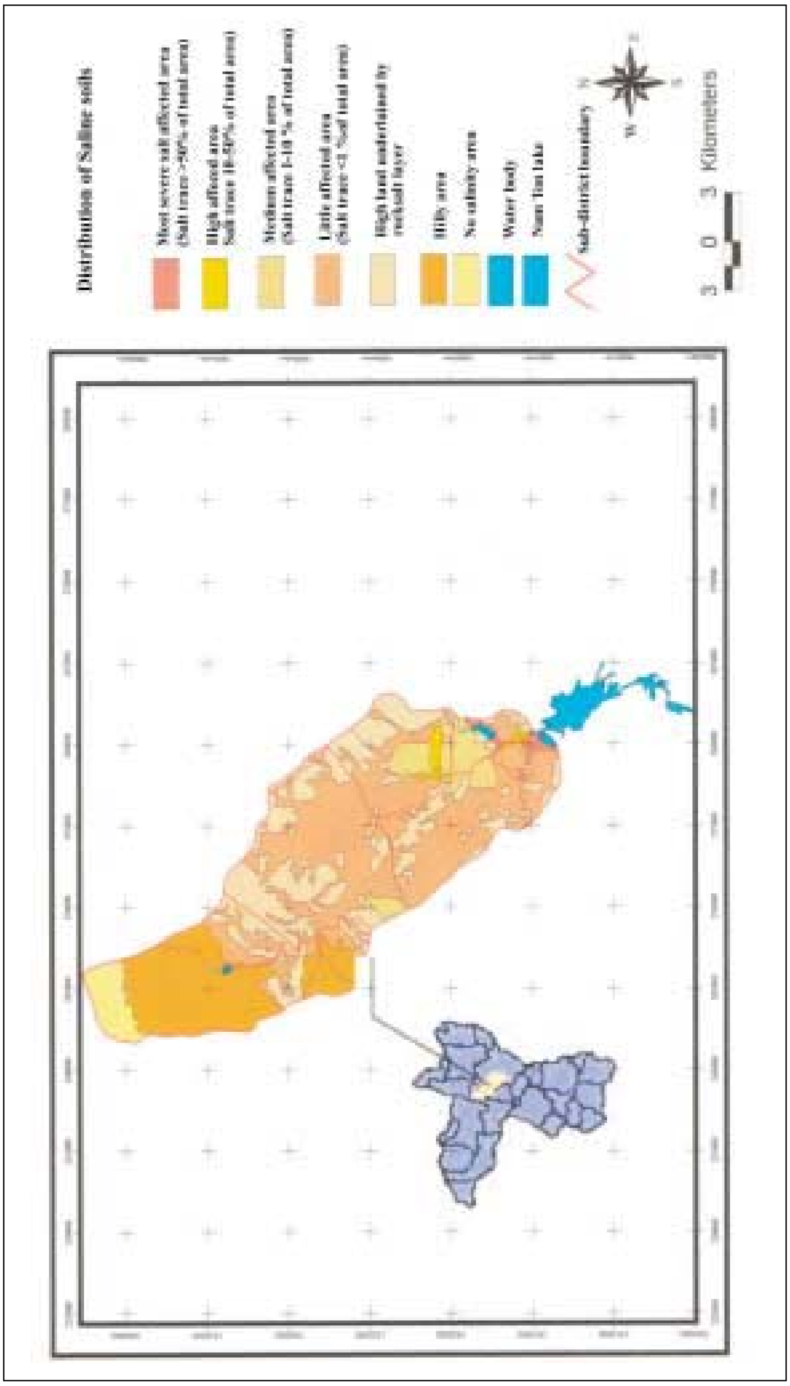

Figure 3. Problem soils of the Huai Yai basin.

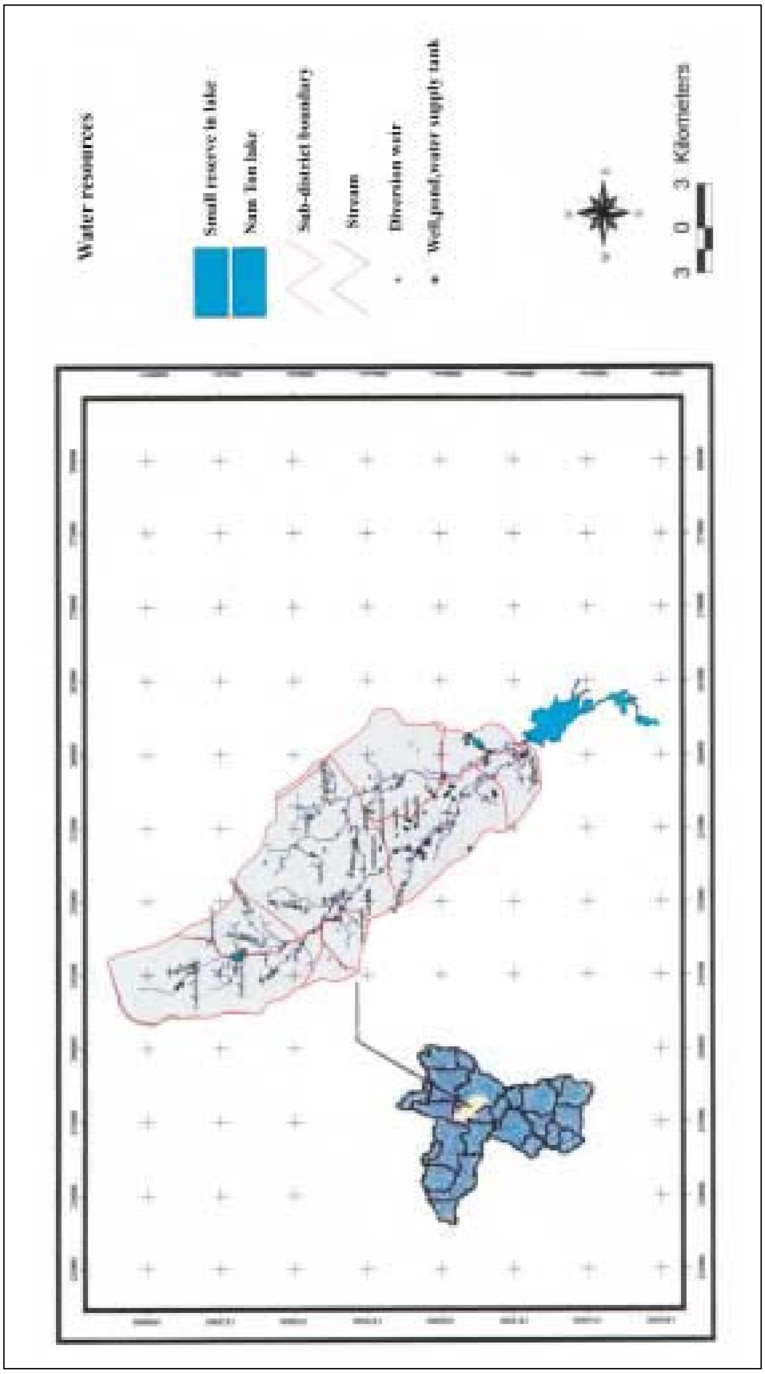

Figure 4. Water resources of the Huai Yai basin.

The Management Tools

The research framework

The philosophy of the project in the Huai Yai basin is to empower the local people to manage their natural resources in a sustainable fashion. It is believed that, in order to achieve this goal, there must be an organisation of stakeholders in the basin to oversee all resource development activities. Therefore, the establishment of (and development of support for) the basin working committee is the main objective of this project. To facilitate the committee's work, the project is also developing a geo-engineering information system and an integrated resource management simulation model. The project's framework is shown in Figure 5.

The basin working committee

After two meeting of representatives from line agencies, local administration organisations (the district and the tambon (sub-district) administration organisation or TAO) as well as the researchers, the basin working committee was established in June 2000. The committee consisted of representatives of organisations mentioned above with the total number of 58. The percentage ratios of government officials to local people and researchers are 72:22:6, respectively. Note that the number of government officials on the committee was very high.

In order to carry out activities more easily, the committee was divided into five subcommittees. These covered water resources, land resources, forest resources, social development and professional development. Each subcommittee selected its own chairman and separately set-up meetings to plan and implement activities. Activities carried out by each subcommittee were reported at the basin working committee meeting, which was held about four times a year.

The water resources subcommittee has been the most active subcommittee so far, and this might be attributed to the participation of the provincial irrigation engineering department. Also, the chairman of the water user association of the Huai Yai irrigation project is an active and enthusiastic member. The forest resources subcommittee has also been quite active, while the other three subcommittees were not so active.

The geo-engineering information system

Basic data such as topography, land use, soil types, problem soils, water resources, roads, bridges have been collected from satellite images, topographic maps and field visits in order to set up an information system called the geo-engineering information system. The system will serve as a tool that

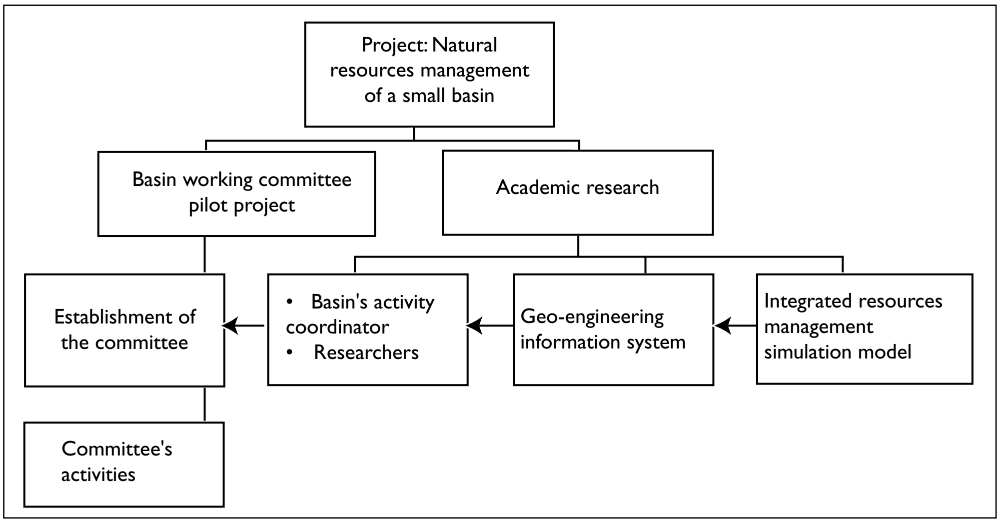

Figure 5. The project's framework.

the basin working committee can use and update for resource management purposes. The maps illustrated in Figures 1–4 are products of this information system, and Figures 6–8 further illustrate the detail contained in the database.

The integrated resources management simulation model

The integrated resources management simulation model developed by the Mekong Committee (Anon. 1982) for the Nam Pong basin was modified for the Huai Yai basin. The model has four systems, namely the water system, the land-use system, the reservoir fishery system and the socioeconomic system.

The water system simulates surface run-off and streamflow through a network of weirs and reservoirs in the basin. The surface run-off process employed the U.S. Soil Conservation Service method (UCSCS 1972) and the streamflow routing employs the method developed by Sa-ngiamsak (1996).

The land-use system simulates the land-use pattern in the basin. It also simulates land-use change and the impact of land-use change on the environment, e.g. soil erosion and sedimentation effects on the life of reservoirs.

The fishery system simulates fish production in the reservoir, which is closely related to the water storage situation and the land-use pattern in the reservoir catchment.

The socioeconomic system simulates the demographics of the basin's population, and the impacts of land-use change and water consumption on the incomes of the people.

Lessons Learned

Lessons learned after one year of the project's implementation can be described under the following headings:

- the management institution;
- participation of the local people;
- the roles of agency officials;
- the role of the basin activity coordinator; and
- the simulation model.

The management institution

The basin working committee has too many members in general, and too many government officials in particular. This creates difficulties in organising meetings and in implementing activities. The division of the committee into five subcommittees has proven to be effective. One important problem is the lack of funds to implement the resource management activities. However, there are potential funds within the TAOS that will be tapped in the near future.

It is recommended that the local people should form more than half the committee membership during the implementation period, and that after about five years they should make up the entire committee membership. At that stage, the government officials could participate with the local people in the form of an advisory body, since they are still the ones that channel most of the development funds into the area.

Participation of the local people

The project encouraged participation of the people in the basin in resource management activities in several ways. One main activity was the establishment of natural resources conservation committees in the villages. Such committees consist of five to seven villagers. The tasks of the committee include stimulation of a natural resources conservation culture among villagers, and planning and implementing natural resources conservation measures. However these tasks have yet to be carried out. At present, the involvement of the basin's people has been confined to several types of committees, farmers in irrigation projects, and farmers involved in reforestation activities undertaken by the forest resources subcommittee. For example, the water resources subcommittee carried out the water resources development plan for the fiscal year 2002, and organised irrigation project training courses that saw the participation of a number of water user groups within the basin. It is believed that, if the project can be extended for a few more years, it can broaden the participation of local people to a greater area of the basin.

The roles of agency officials

Though agency officials constitute a majority in the working committee, very few are active. Active officials include the provincial irrigation officials, some forestry officials and some land development officials. It is recommended that, over time, as the local members gain more experience, the agency officials should play advisory roles rather than committee roles. This transfer of the responsibility should be carried out gradually as mentioned above.

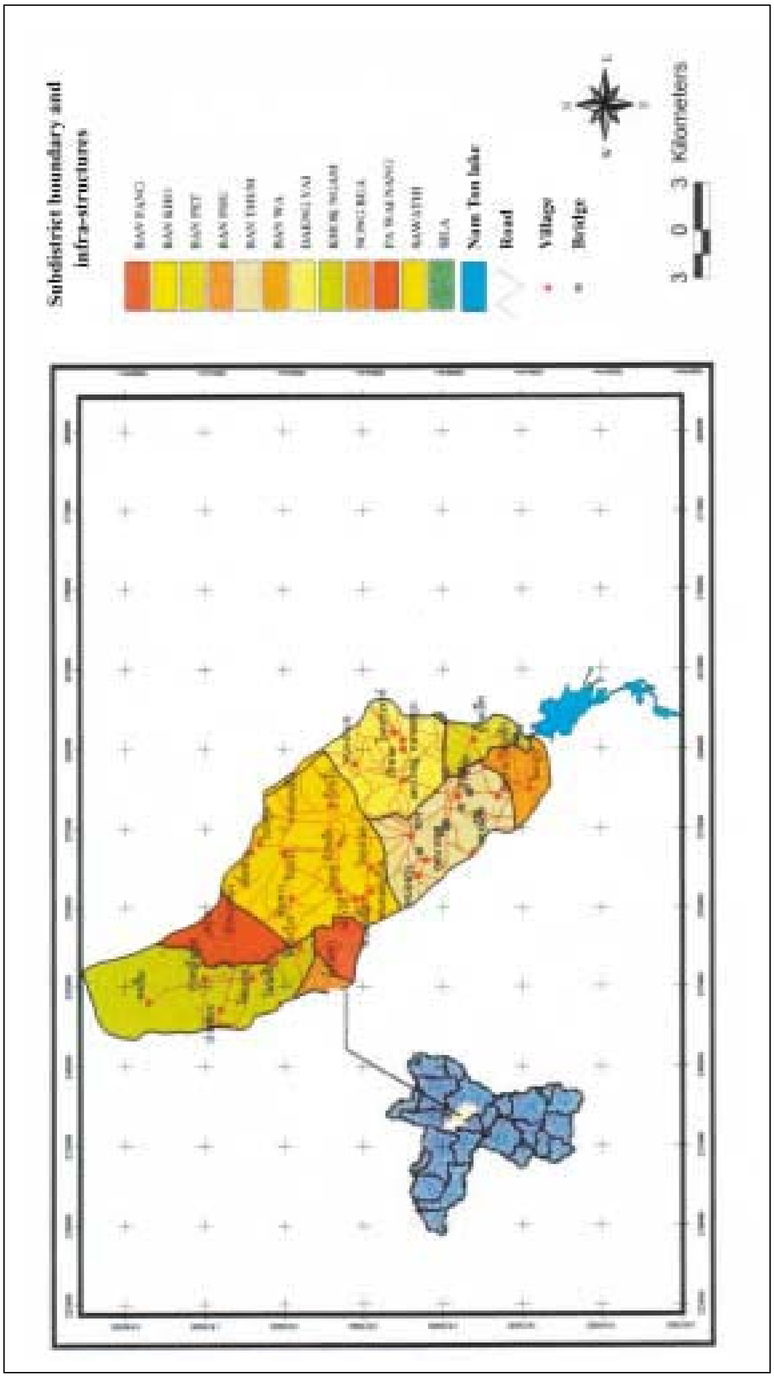

Figure 6. Administration boundary and road network in the Huai Yai basin.

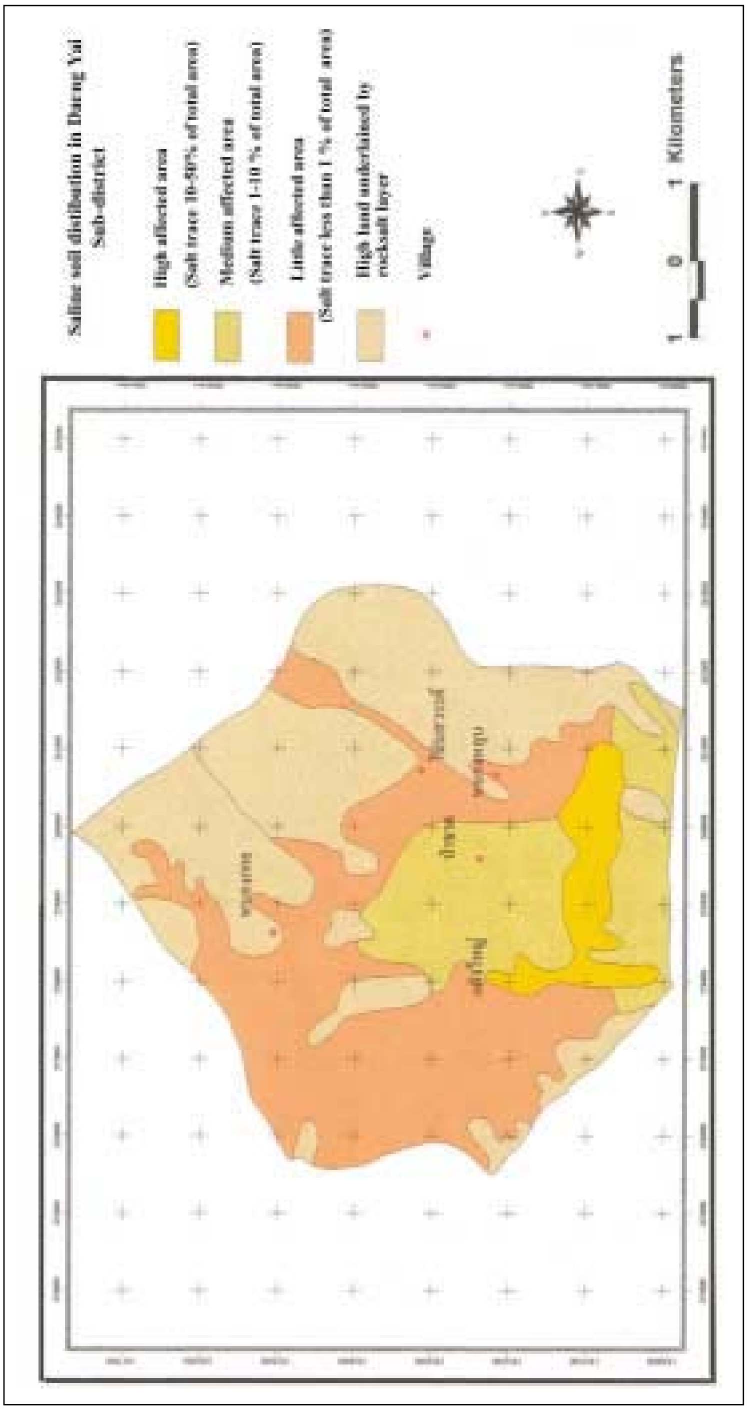

Figure 7. Saline soil of one sub-district.

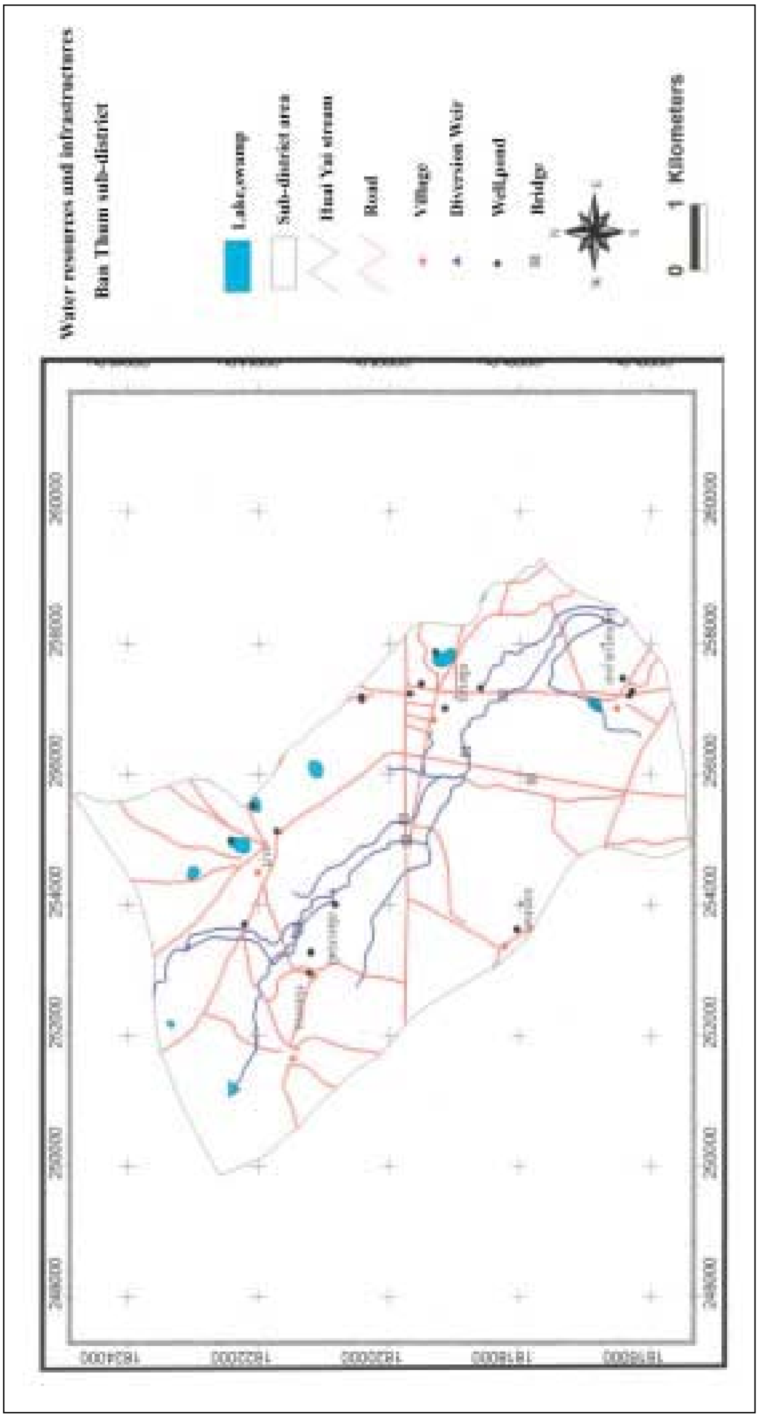

Figure 8. Water resources and other infrastructure in one sub-district.

The role of basin activity coordinator

The basin coordinator is an essential component of this project. The tasks of the basin coordinator include serving as a secretary of the basin committee, organising meetings, coordinating the implementation of other activities, editorial board member of the basin's newsletter, collecting research data, etc. It is recommended that the basin coordinator should spend most of the time in the area so that liaison with the local people can be undertaken in the evening when they are free from daily farming activities. This can speed up activities and draw more people's participation. And since the coordinator's tasks are numerous, the appointment of two basin coordinators would be more effective than the current single position.

The simulation model

At present, the development of the simulation model is not complete. Some model parameters need to be calibrated against available data. Some parameter values can be only roughly estimated. The socioeconomic component is not finished. The model as a whole is yet to be integrated. This model will be demonstrated to the committee and modified according to comments and suggestions in the second year of the project.

This project has been planned as a five-year activity with two phases. Phase I has a duration of two years with the aim of having a well-established basin committee and working tools for the committee as mentioned in this paper. Phase II, with a duration of three years, will involve research and documentation of the concept's implementation, refinement of the tools developed and dissemination of research results at the national level. Unfortunately, the budget for the project was available for only one year and ended in May 2001. So, a number of activities planned will not be implemented and it is doubtful whether the working committee for the Huai Yai basin will be able to sustain its status and activities.

Acknowledgment

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Water Policy in Practice — a Case Study from Vietnam

Hugh Turral* and Hector Malano†

Abstract

Vietnam has experienced great economic and administrative change since the 'open-door' policy began in 1989. There is considerable variation in the institutional arrangements for water management, depending on the perspectives of provincial administrations the length of the country as they respond to the reform process. Economic pressure to reform water management, through the removal of subsidies, was applied until 1999, when the policy was reversed. Programs to hand over greater autonomy and ownership of irrigation infrastructure to farmers have had little impact, especially in formal systems in the Red River Delta. Nevertheless, Vietnamese farmers pay considerably more for their water than most of their counterparts in Southeast Asia, and fee collection rates are surprisingly high. These fees do not cover the full cost of service and are area-based taxes, which do not encourage improved service provision by the state-owned semi-autonomous irrigation companies.

ACIAR has sponsored collaborative research at three irrigation systems, which each service approximately 10,000 ha, two in the Red River Delta, and one close to Ho Chi Minh City in southern Vietnam. The projects have tried to integrate simple programs of flow monitoring and hydraulic modelling to evaluate and improve service and link this with the development of umbrella water user associations on secondary channels. These groups amalgamate effective, commune-based management units, which have not historically cooperated well to achieve equitable water distribution. The projects have also introduced asset management systems in order to determine the full cost of irrigation service, and to link with diagnostic modelling to determine optimum strategies for rehabilitation and modernisation, based on acceptable service and acceptable cost, both to farmers and irrigation companies.

The current emphasis of these projects is to scale up the institutional development and operationalise the management package on a day-to-day basis at each of the irrigation companies.

Public Irrigation in Vietnam

VIETNAM lies in the tropical monsoonal region with abundant rainfall averaging 1800 mm but with a very uneven distribution. Rainfall in the wet season accounts for 80–85% of the total annual amount. Irrigation plays a critical role in the development of agriculture and food supply in Vietnam in general and in the Red River Delta (RRD) in particular. The Red River Delta contains some 850,000 ha of the country's 3.5 million ha of irrigated agriculture. Most of the irrigation area in the Delta (699,233 ha) is supplied by pumped irrigation schemes with the remaining 252,000 ha being supplied by gravity. There are 31 irrigation schemes with some 1700 pumping stations and 7600 pump sets. The installed pumping capacity for irrigation and drainage in the Delta is 261,000 kW which translates into a rate of energy input for irrigation and drainage of 250–300 kilowatt hours (kWh)/ha.

The high energy cost required to operate these systems (typically 30–35% of the total operating costs including capital) is a cause of great concern to operators and managers of these schemes. This substantially reduces the ability of irrigation companies to maintain an adequate level of expenditure on maintenance, and leads to a rapid decay of the irrigation

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infrastructure. An inadequate delivery infrastructure creates widespread problems of reliable and timely supply of water to irrigators.

Formal irrigation systems are rare in the Mekong Delta, where water retention and control are practised in conjunction with groundwater exploitation. There are several big reservoir-supplied canal systems outside the Mekong Delta, on the Saigon and Dong Nai rivers.

Rice accounts for the bulk of the irrigation area and water use in the country. However, dry-footed crops are becoming increasingly important because of self-sufficiency in rice production and better market prices especially for maize, potatoes and vegetables. The increasing adoption of a cropping pattern composed of three crops per year in the majority of the irrigation area creates new demands for water both in quantity and in the flexibility of supply.

In Vietnam, 'water law' is administered at the national level, and implemented by the many provinces. The implementation and administration of water laws tends to vary between provinces, as provincial regulations must also be passed to support national legislation. Of the nine river basins in Vietnam, the Red River, the Mekong River and the Dong Nai are by far the more important economically. There are many provinces, often within a single river basin—for example, 26 provinces in the Red River Basin, 10 in the hill districts and 16 in the lowland (Figure 1).

There is a more general problem in that the implementation of contractual and property/allocation disputes relies on a more generally established legal framework and forums for arbitration which do not exist in modern Vietnam, although much effort is being put into the establishment of a comprehensive and independent legal apparatus. The idea that the state or organs of the state are accountable to individuals, though the process of law, is yet young.

The Law on Water Resources (1998) has been through a lengthy gestation of more than 17 drafts, with much of substance removed in the later stages of the process. The law is conceived as enabling legislation, which requires the development of further supporting regulations and codes at both national and provincial level. However, this approach requires a long planning horizon, as, historically, regulations have been specific and interpreted extremely literally. Hence, many provincial administrations can rightly note that the law does not specifically require them to do many things at all.

The law makes provisions for the maintenance of quality of water resources and makes multiple references to management and exploitation at the river basin level. However, it specifies an over-arching National Water Resources Policy, to be determined by higher levels of government, while promoting the Ministry of Agriculture and Rural Development (MARD) as the non-profit management and planning organisation for river basins and smaller catchments. Therefore, at present, both service and regulatory aspects of water resource management are undertaken by the same agency.

The law encourages stakeholder participation but has nothing prescriptive to say at all about how or when this will be done and it has decreed that where people are disadvantaged by changes to water management procedures they shall be compensated. It is not clear how this would be achieved in practice, as there is no effective water-accounting system in place to actually allow the quantification of any such changes (ADB 2000). Initiatives in water quality are similarly hampered by this lack information on flows, and therefore on pollutant loads and their spatial and temporal distribution.

There has been a national program for participatory irrigation management (PIM) since 1997, but it has had limited impact. Resistance to turnover and PIM is heightened over concerns about the employment and redeployment of irrigation service staff, should management transfer become widespread. The fundamental motivation for management transfer is severely blunted by the national policy of providing subsidies for both operation and capital investment in rural water systems, especially drainage. Vietnamese managers and planners do not take seriously donor initiatives to improve management under terms of loan agreements of irrigation rehabilitation and modernisation. They believe that infrastructure improvement is of paramount importance and that the development banks (the Asian Development Bank and the World Bank) are primarily interested in disbursement as well. Consequently, there is no funding priority for implementing institutional reform and no evident support, particularly at the provincial level, for the Ministerial Decision No. 1959/BNN-QLN (issued 12/05/98) promoting low-level reforms and participation in irrigation management.

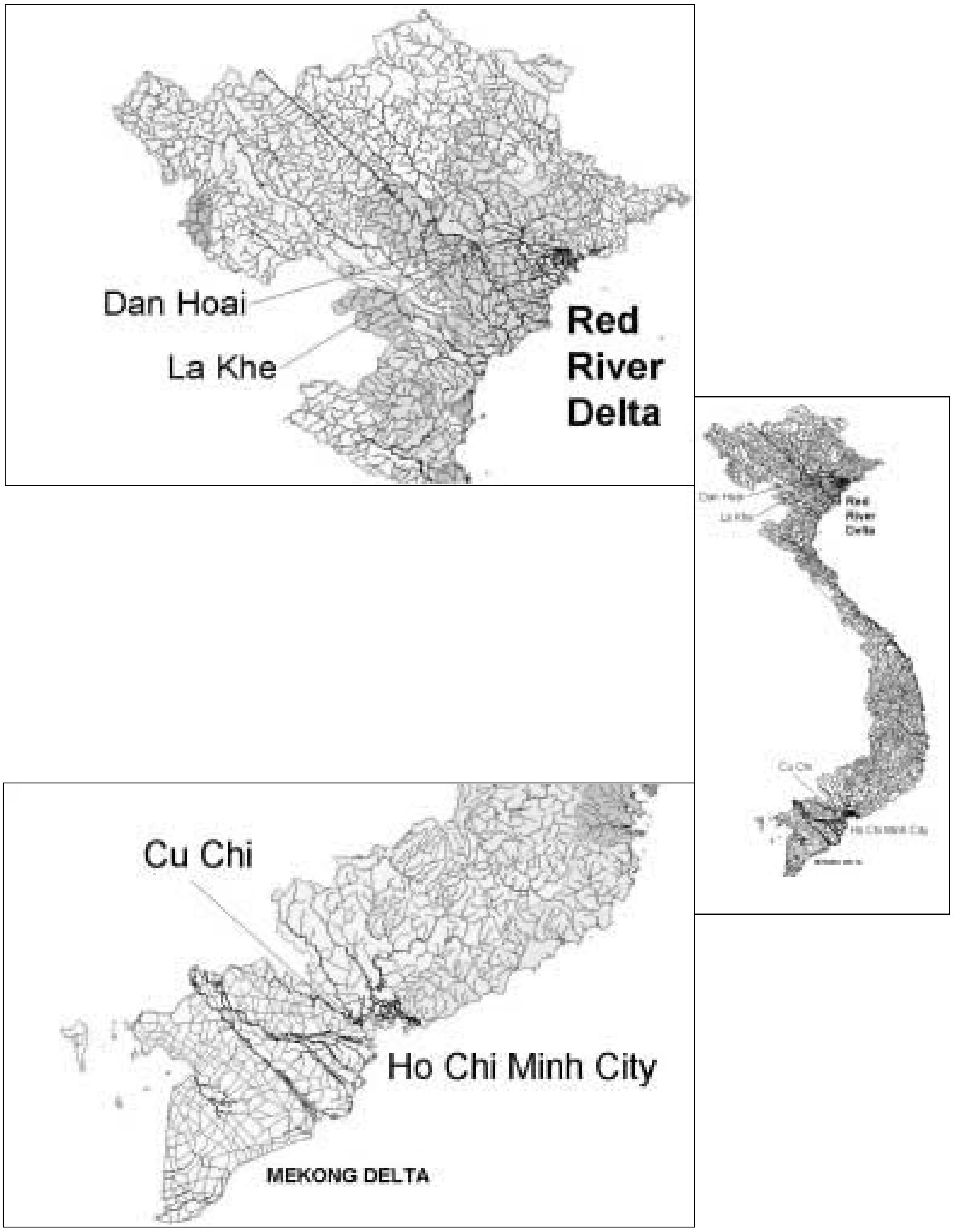

Figure 1. Map of Vietnam showing province and river basin boundaries and the location of ACIAR project sites.

The unit responsible for PIM in MARD has also been given the task of overseeing water-pricing reform.

Organisational structure

The administrative structure of government in Vietnam is both decentralised (notably at the provincial level), but also highly parallel, with both party and civil hierarchies at provincial and district levels. Provincial boundaries continue to be in a state of flux with both consolidation and subdivision in recent years. One reason that MARD is being forced to take control of bulk water supply companies (Bac Hung Hai and Bac Nam Ha) is that multiple provinces find it impossible to agree on funding and administrative issues, especially following administrative restructuring. This is one example of a system that is tending to recentralise more broadly as considerable aid-flows are channeled through central government organisations. Such 'centralisation' does not actually mean a simplification of the institutional landscape, as many departments have overlapping jurisdictions and interests. For example, a recent feasibility study for a water quality project in the Red River Basin found that there are more than 12 agencies with 'responsibility' for instream water quality, including the police and the military (ADB 2000).

Bulk supply companies (the Irrigation and Drainage Management Companies—IDMCs) are operated by provincial administrations, but where they cross multiple administrative boundaries, they have increasingly been brought under direct control of MARD. The key reason that has precipitated this development is that bulk supply companies are in serious financial difficulties due to non-payment of bulk fees and limited ability or will to restrain operational costs. Where bulk supply companies have been taken on by MARD or cross multiple jurisdictions, the irrigation companies are owned and managed by the individual provinces.

The irrigation companies (called 'district enterprises', DEs) are semi-autonomous management units under provincial control and direction. They are responsible for the operation and maintenance of main and secondary channels and investment in their improvement. Water supply in the RRD is generally pumped because of the dike system, and a large amount of secondary pumping is practised due to limitations of the canal network and its operation.[1] Most drainage is pumped, especially during periods of high river flows, when gravity outfall to the rivers in impossible.

A schematic of the organisational landscape is shown in Figure 2 for Ha Tay Province in the Red River Delta.

Communes are responsible for water management and investment at tertiary level and below, via the agricultural cooperatives (HTXs) and their water management groups (WMGs). The HTXs were recently reformed (1999) as multifunction organisations with 'voluntary' membership. The WMGs are based at a village scale, and tend to manage water distribution for individual farmers—partly a hangover from the old commune system and work teams, but also as a consequence of the highly disaggregated landholdings resulting from a 'fair' land allocation policy in land reform. Farmers own the leasehold to their land only, which in theory may be traded, and some land consolidation has been occurring informally and is the subject of policy debate at a higher level.

Irrigation and drainage pricing policy

Irrigation service fees are set nationally, capped at a guideline value of 8% of seasonal average yield in kg/ha. In practice, fee rates are set by each province and have not been revised for some time, so that they more typically run at around 4% of actual yields. Different provinces have different policies on drainage fees. In Viet Tri (Phu Tho) and Phi Xa (Hai Duong), drainage levies are made of about 2% (90 kg), but in Ha Tay, Nam Ha and many other provinces, they are nominally incorporated into the irrigation fee (260 kg/ha/season on average or US$24/ha, which is roughly equivalent to 0.3 US cents/m^3). At La Khe, the average water revenue calculated was $A5.85/ML

1. A significant proportion of the irrigation infrastructure in the Red River Delta was constructed in the early 1960s. In many cases the main canals were designed, but the undershot gated regulators were not intended to control supply level, but merely to open and close different canal reaches. Secondary canals in many cases were constructed 'on-site' and appear to have had limited design input. These two factors, coupled with significant deterioration of the infrastructure, have not provided gravity supply to many parts of the design command area. A large secondary pumping capacity has been installed to maintain or improve service to farmers, especially on channels that are used both for water supply and drainage, which is another common feature of these schemes.

(0.22 US cents/m^3) at constant 1996 prices. Irrigation fees are assessed in three classes: full gravity supply; partial gravity supply; and an extraction charge for water pumped or diverted from local sources by users.

There is much scope for 'negotiation' in the classification of irrigation supply in many areas, as the area receiving full gravity supply may change according to the effectiveness of water level control in the main channel and due to knock-on effects of river levels in the main supply system.

At present there is no attempt to recover any capital cost in construction or modernisation of systems. This policy is unlikely to change in the foreseeable future, in part due to the very significant amounts of 'voluntary' labour committed to irrigation system construction between 1960 and 1990.

Drainage fees do not reflect the actual expenditure in pumping water, and DEs and IDMCs have to reclaim excess costs from central government subsidies. Additionally, different provinces set different thresholds at which there are pro rata reductions in irrigation fees according to the estimated loss sustained from inundation. Where drainage charges are levied, there are no concessions except when there is total crop failure and no charges are levied.

The costs of drainage provision are a major financial burden to IDMCs and DEs, which are often obliged to take short-term loans to pay electricity charges until subsidies and service fees are received. From 1995–99, central government policy was to remove operational subsidies for irrigation, but this was reversed following rural unrest in 1998.

Drainage operations that prevent complete crop failure have a high economic value. However, repeated drainage of events that cause small reductions in crop yield have a much more precarious cost–benefit ratio. Similarly, repeat pumping from tertiary

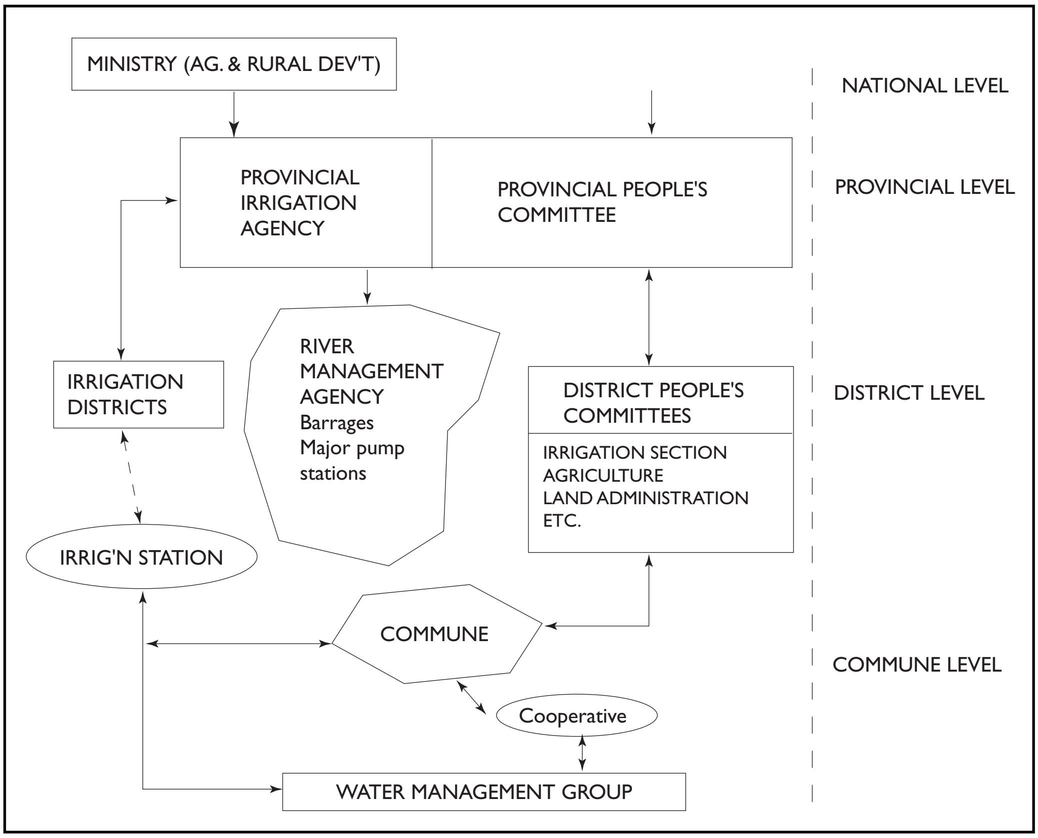

Figure 2. Management organisations for irrigation and water resources in Ha Tay Province.

to secondary, from secondary to primary and from primary to the river system, considerably compounds costs, although the lifts in the intermediate stages may be small (around 1 m).[2] If farmers were to pay full drainage costs, this burden would be much more evenly distributed and, in many years, the incremental cost would be of the order of 9–30 kg/ha. The cost of draining 100 mm excess rainfall, lifted through 3 m would typically cost around Vietnamese dong (VND) 6,000–20,000 or 0.1–0.3% of a conservative total yield of 3 t/ha.

Fees are payable on spring and summer crops in the RRD, but winter supplies are subsidised to encourage expansion of winter cropping. In the south (at Cu Chi), fees are levied on only two cropping seasons despite significant areas of continuous cropping.

Electricity remains subsidised and domestic supply is more expensive than irrigation power. External donor pressure for price reform indicates that charges should at least double to reflect the true cost of generation. Such an increase would substantially change the cost profile of the irrigation companies and electricity, especially when heavy drainage pumping is required.

Service fee recovery

Service fee collection systems vary throughout the country. Within the Red River Delta, the commune system is strong and provides a framework for fee collection and assessment. Outside the delta, the commune system has largely broken down, despite efforts to reform and revitalise the sector. In this situation, irrigation companies have to pay much closer attention to area assessment and collection, and mobilise significant teams to do this (namely North Nghe An and Song Chu). Bulk fees are paid by DEs to their provincial agency/bulk supply company: at La Khe, the bulk charge averaged VND6/m^3 (0.04 US cents/m^3) over the period 1992–1996.

Fee recovery rates are generally high. Typically, irrigation companies claim 98% fee recovery, but analysis of balance sheets for La Khe and 14 DEs in Bac Hung Hai (ADB 2000) indicate the true figure to be 75–85%, which is still impressive by the standard of most Asian countries. However, there may also be some creative accounting on the actual areas from which charges are due.

Local fees for tertiary water management are charged to cover WMG operation and distribution costs. They are collected in tandem with company fee and with land tax. Typical rates are about 125 kg/ha or about US$11.70/ha.

Income for agricultural cooperatives is very largely derived from water charges, following broader (private) provision of fertiliser, seeds, and postharvest processing facilities. Irrigation fees and land taxes are collected by WMG staff, on behalf of the cooperatives and their parent communes. There is therefore considerable self-interest involved in maintaining control over tertiary level water management and using this as an entree for the provision of other services such as land preparation (rotor-tiller hire) and postharvest processing.

True cost of supply

Even though fees are relatively high in Vietnam, they do not cover the true cost of water supply. This will be discussed in detail with reference to La Khe, which may be considered typical of a pumped irrigation system in the RRD. Deferred maintenance is the norm, and rehabilitation is normally replacement of existing assets rather than improvement of the infrastructure. Channel lining has become a high priority, using international loan finance, but scant attention is paid in general to improving the operability of systems or improving water level and discharge control.

There is no standardisation in structures, and therefore few economies of scale in manufacturing. Three separate design codes are in use and there is a strong need to rationalise and revise one set of national standards.

In the longer term, irrigation pricing will be very sensitive to electricity price as doubling it would increase the cost of service at typical pumped irrigation systems by 25%.

ACIAR Water Management Projects in Vietnam

ACIAR funded the collaborative research project ‘Integrated management of pumped irrigation systems in the Red River Delta’ (ACIAR Project 9404, 1999), from 1995 to the end of 1998. The objectives of the project were to integrate technical improvements in water management with appropriate

2. For instance at Bac Hung Hai.

institutional arrangements in order to improve the level of service to farmers. The project had three components: irrigation system operation; farm-level water management; and institutional development. The economic aspects of each subprogram were also investigated.

Research was undertaken at the 8,600 ha La Khe Irrigation System (LKIS), close to Hadong Town, some 20 km south-west of Hanoi (see Figure 1). The research was conducted by the Vietnam Institute for Water Resources Research and Hanoi Agricultural University. The Australian partners were the University of Melbourne, CSIRO and the Centre for Water Policy Research, University of New England, Armidale.

A second project 'System-wide water management in publicly managed irrigation schemes' (ACIAR Project 9834) is in progress, and aims to put the findings of Project 9404 into practice at three sites, La Khe and Dan Hoai in the north of the country, and Cu Chi, which is close to Ho Chi Minh City (see Figure 1). The project is trying to develop rapid methods of implementing the management system developed by project 9404, and is continuing with the gradual process of institutional development. It is also engaged in research into the use of remote sensing to map rice area by growth stage, to allow for better modelling of demand and scheduling of supply. The project is also making more detailed investigation of tertiary level water balance, with assistance from the International Rice Research Institute.

Improvements in system operation have focused on using computer modelling to estimate demand, coupled with manual flow monitoring to estimate supply and determine how well demand is satisfied over the command area. Models of the irrigation systems have been developed which describe the main and selected major secondary channels. The model IMSOP[3] was used to develop alternative flow rules, including rotational supply to overcome capacity limitations at peak demand periods, such as land preparation and land soaking. Modelling and diagnostic survey were used as tools to specify a service agreement which has not yet been formally implemented.

Economic research in the project includes analysis of water pricing reform and the development of pilot volumetric pricing at La Khe.

3. Irrigation Main System Operation Model.

A plan layout of the La Khe Irrigation System is shown in Figure 3.

Diagnosis of system performance and service

A formal socioeconomic survey was conducted at 126 villages in 26 communes within the LKIS command area, in 1996. The survey concluded that the WMGs and HTXs are fully functional groups, but that cooperation in water sharing between communes along shared secondary canals left much to be desired. The survey indicated widespread problems in the timing and quantity of irrigation supply, particularly at the tail of the main system and at the end of major secondary canals. The survey noted that while a very high proportion of farmers pay their water fees to the HTX, the full payment is not always passed on to the irrigation company.

A diagnostic survey of operation at La Khe was conducted in 1997, along the main canal and along three major secondary canals, which together account for about 15% of the total service area. The diagnostic survey highlighted severe head to tail inequity and showed that canal and hydraulic regulator capacity in the first two reaches of the main canal severely limited the available flow downstream as shown in Figure 4 (Turral et al. 1998a,b). Tail-end water levels were shown to fluctuate considerably, mostly being too low to command the design service area. The survey also showed that, in practice, the company was not operating the secondary canals, or controlling 'illegal' diversions directly from the main canal in the first two reaches. There was no formal control of water level in any of the secondary channels, resulting in very erratic supply level. Coordination between neighbouring communes was poor to hostile. Significant volumes of water diverted into two head-end secondary canals were diverted directly into the drainage system when not required at farm level.

Manual flow monitoring confirmed the pattern of water distribution found in the diagnostic survey. Automatic flow monitoring at selected sites showed considerable fluctuation in supply levels, and confirmed that low level of supply is a major factor contributing to poor service at lower end of system.

Poor water delivery to the tail-end of the supply channels means that farmers effectively pay twice for bad service. The exact amount of re-use of return flows is not known and in practice quite hard to trace, which is the reason for further investigation of the tertiary level water balance in Project 9834.

Continued flow monitoring at La Khe has shown considerable improvement in the equity of water distribution since 1997, following a 2-week trial operation of the canal using modelling results in 1998. This work was followed by some channel improvements in the second reach of the main canal, using communal labour and company funds, and a complete refit of all offtake doors from the main canal. Monitoring in 2000 showed that water supply at the fourth regulator (bottom 18% of the command area) satisfied 70% of calculated demand, while the maximum oversupply at secondary channels near the headworks was reduced to 140% of demand. Water level control in the bottom half of the system also improved markedly following payment of operational incentives to field staff from 1998 onwards.

Modelling

Irrigation system operation is simulated with a simple steady-state model, known as IMSOP, which calculates crop water demand from climatic data collected from automatic weather stations installed at the site. The Penman–Monteith procedure is used to calculate reference crop evapotranspiration, which is converted into crop water requirement for each crop, and planting date specified in the crop pattern. Total water requirement (including deep percolation) is accumulated at each designated offtake, then offtake requirements are summed from the tail to headworks to determine pump operation or reservoir release schedules. Simple hydraulic calculations are performed to predict flow levels and gate openings.

The model is used to analyse past performance of irrigation delivery, to plan forward schedules on seasonal and near-real-time operations and to investigate alternative flow rules. It can also be used to investigate changes to the irrigation infrastructure to improve the operability of the system. It is designed to be used in conjunction with the asset management system, in

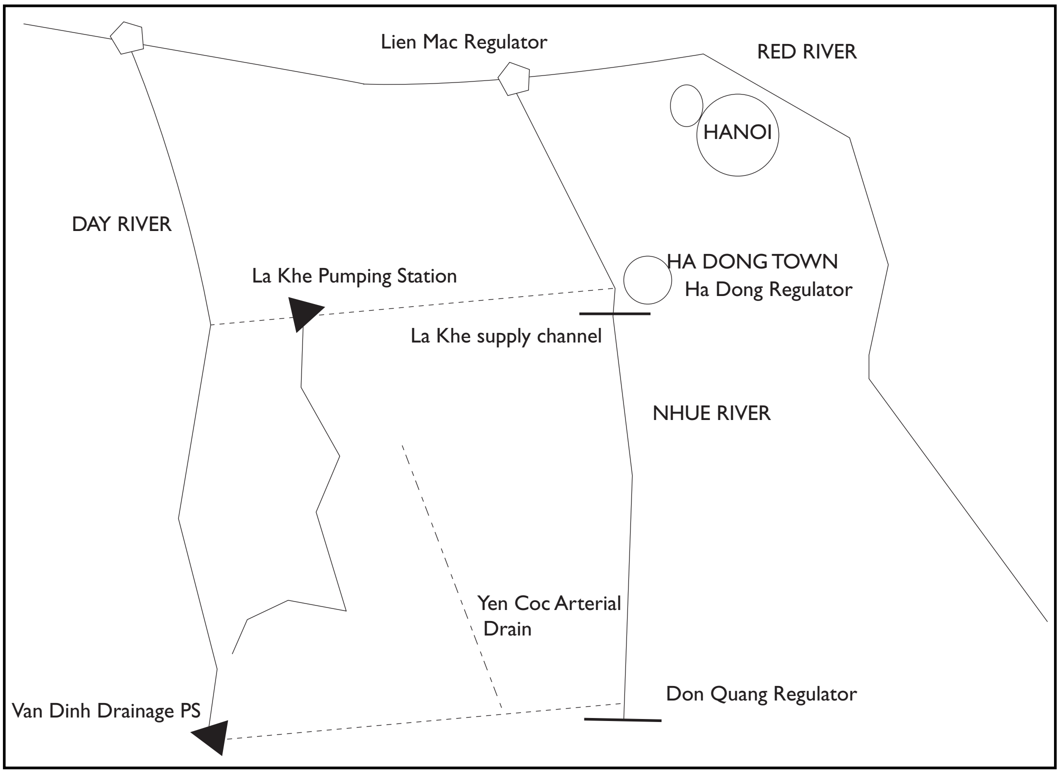

Figure 3. Schematic layout of the La Khe Irrigation System.

order to determine economically attractive modernisation that will result in improved service.

Modelling and flow monitoring determined a general pattern of seasonal over-supply in spring, and under-supply in summer, when heavy rainfall is expected during dry periods, making the company reluctant to supply water until maximum pressure is exerted by users.

Cost of service

The approach taken to determine the cost of service at LKIS relied on a combination of expenditure data for the period 1992–96 provided by the company and information collected through the asset survey. The cost figures provided by the irrigation company were aggregated into six categories as follows:

- power cost for irrigation;
- power cost for drainage;
- maintenance;
- bulk water fee—fee paid to Nhue agency for bulk water supplied to La Khe Company;
- personnel—this item includes full time staff, casual wages and staff on-costs; and
- overheads—this item includes administration expenses, collection of water fees, taxes and miscellaneous expenses.

Asset annuity cost

The depreciation component was calculated using a renewals approach based on the residual life of assets and indexation figures using the Government of Vietnam official inflation rates. A relatively low level of maintenance expenditure is observed in relation to other costs, chiefly power and asset annuity, which explains the poor condition of the infrastructure.

Figure 5 depicts the aggregated investment profile over the next 40 years, based on the survey of asset condition carried out at La Khe. The system infrastructure will require a large number of renewals within the next decade as a result of its deteriorated condition. The investment profile becomes very lumpy as certain groups of assets (structures, channels, pumps etc.) wear out at similar times.

A 40-year investment plan was developed to smooth out the lumpy configuration of the required investment. It must be recognised, however, that such a plan would require periodic reviews to allow adjustments needed to account for the changing macroeconomic conditions and deviations between predicted and actual conditions.

The analysis of the cost breakdown shows that power cost accounts for 25–40% for the period analysed, which includes 1994, a year of high power use for drainage due to high summer rainfall. A comparison of system operation costs with actual revenues is provided in Figure 6, assuming no rate of return on the infrastructure investment. The average revenue for the period analysed was US$40.00/ha while the average cost of operation was US$52.00/ha (exchange rate US$1 = VND14,500). This calcula-

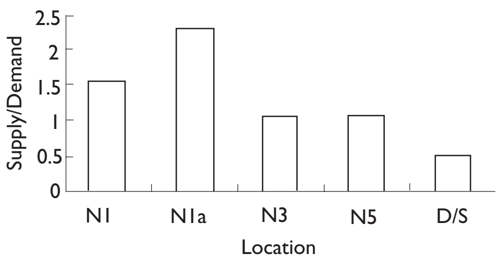

Figure 4. Demand and supply at upper secondary channels (N1–N3) and in the lower command area (d/s), Spring 1997.

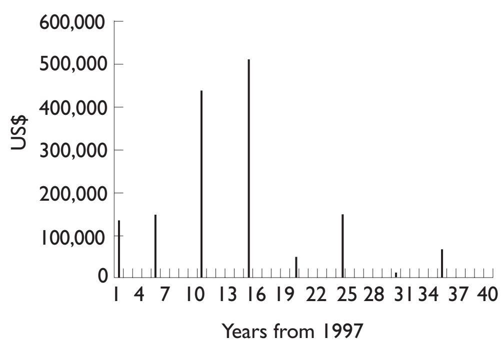

Figure 5. Investment profile for La Khe irrigation scheme.

tion is based on the total invoiced water charges and does not take into account the actual collection rate for La Khe which varies between 63 and 88% and shows a declining rate over more recent years.

Currently, there are no formal provisions made for depreciation, except for minor payments made by the La Khe Irrigation Company to the provincial government in 1992 and 1993.

Infrastructure renewal strategy

Main system

The delivery of irrigation and drainage service requires a hydraulic infrastructure that is designed, operated, maintained and upgraded in the most cost-effective manner to meet clear service objectives.

Low performance of irrigation assets may be due to poor condition caused by poor maintenance practices or by inadequate selection and hydraulic design or a combination of both. At La Khe, the type of hydraulic control employed in the main canal limits the flexibility with which the existing system can be operated. The combination of undershot cross regulators and gated offtakes causes hydraulic instabilities in the water level in the main canal that tend to amplify the discharge fluctuations through the offtakes. The appropriate use of overshot cross regulators would greatly simplify the flow control through the offtakes and reduce the discharge fluctuations that occur through them.

The hydraulic modelling analysis carried out for the main canal revealed capacity constraints in the main canal imposed either by the condition of the canal embankment, the siltation of the canal bed or the capacity water level regulators.

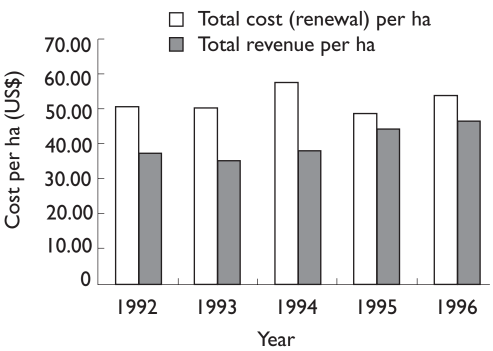

Figure 6. Revenues and system costs for La Khe (0% rate of return).

These constraints occur both under the existing operation and the proposed operation. A comprehensive modernisation of the upper main channel would increase the first regulator capacity from its present limit of 10 m^3/s to 12.5 m^3/s and that at the second regulator from 7 to 10.5 m^3/s. The head and second reach dimensions need to be increased to allow effective water level control to regulate flows and flow level. Raising the channel would be a cheaper option, but would result in slightly higher pumping costs, as a higher dynamic lift would be required. Detailed unsteady hydraulic analysis is required to optimise this design, which could alternatively use a long-crested weir to replace gated regulators. The only unknown factor with respect to the weir is the effect of siltation on the head reach and the recurrent cost of de-silting.

On the basis of the results obtained from monitoring and modelling analysis carried out in this project, the La Khe Company has undertaken a refurbishment program to improve the cross section of the main canal and replace the existing offtakes structures. Table 1 presents a summary of the rehabilitation works undertaken and their cost. The refurbishment program does not include the replacement of the cross regulators which modelling has shown to constrain the discharge during periods of peak demand such as land preparation and planting.

Table 1. Summary of refurbishment works on the main canal.

Item	Quantity	Cost
Widening cross-section	3,670 m	US$3.4/m
Raising embankment	834 m	US$1.7/m
Offtakes	59	US$280.00 each
Total		US$30,415
Cost per ha[a]		US$3.45

[a] Cost per ha calculated on the basis of 8,800 ha of irrigated land.

Secondary system

As indicated above, the asset management program was limited to the main system assets and does not include the lower level distribution infrastructure. The diagnostic survey identified that lack of proper water level control, coupled with inadequate offtake structures, makes the distribution of water very complex.

Water level in the secondary canals is maintained largely by discharge control. There is a diversity of offtake configurations along secondary canals as a result of repairs and replacements made over the life of the system, which makes any attempt to equitably control, distribute and measure water distribution very difficult. Future replacement of offtake structures along secondary canals must consider the possibility of standardising the design, possibly using precast concrete structures that would enable proper measurement of discharge into the tertiary canals.

Secondary canal N5: a refurbishment case study. The formation of a water users advisory committee (WUAC) for secondary canal N5 provided the opportunity to conduct an asset audit of this canal and identify the existing constraints to proper water management along the canal. On the basis of the survey, a preliminary design for the upgrade of the canal was carried out. The design objectives were:

- to modify the current design in order to provide a degree of canal capacity and water level control that would enable an equitable and simple distribution of water along the canal; and
- to achieve this in the most cost-effective manner.

Table 2 summarises the main structural components and costs for the upgrade of secondary canal N5.

Table 2. Cost summary for refurbishment of N5 secondary canal.

Structure type	Number	Cost
Duckbill weir	1	VND24m (US$1,714)
Gated cross regulator	1	VND36m (US$2,285)
Tertiary offtakes	16	VND32m(US$2,285)
Improvement of lined section		VND20m(US$1,428)
	Total	VND112m (US$8,000)

The N5 secondary canal provides service to 773 ha of irrigated land. The estimated cost of upgrade of US$12.00/ha represents an additional charge to the users of US$1.60/ha annually, assuming an economic life of 30 years and an interest rate of 13%. This is clearly a small cost (increase in water charge of 2.7% per annum) for the operational and productivity benefits to be derived from the upgrade.

MARD has adopted a policy of promoting lining of irrigation canals across the country.[4] The success of this policy is often measured in terms of the number of kilometres of canal lined annually. The experience with canal lining at La Khe shows that the cost of this type of upgrade is substantially higher than that of providing adequate water level and discharge control. For a typical secondary canal like N5, the investment cost of concrete lining is approximately $US100.00/ha which translates into an additional payment of $US13.30/ha/yr over a 30-year period at a 13% interest rate. Arguably, these two types of interventions are not mutually exclusive, in that both improvements can be combined, e.g. canals are lined and fitted with adequate water control. However, a more rational approach would be to build improvements in order of decreasing cost-effectiveness to provide a given level of service. With this aim in mind, the provision of adequate hydraulic control is a more cost-effective intervention than the simple lining of canals.

While canal lining has the potential to improve the ability to manage and control water, this benefit can be attained only if adequate water control is provided. Failure to take this into account, or neglect of the need for hydraulic control entirely, will result in failure to achieve any of the perceived benefits of concrete lining.

Extensive experience with canal lining worldwide shows that this type of canal upgrade often fails to achieve the benefits suggested in the planning stage. Rapid deterioration of the lining, accompanied by a rapid increase in canal seepage can quickly offset its perceived potential benefits. The durability and effectiveness of canal lining is related to, among other factors, the mechanical characteristics of the soil, the behaviour of the local watertable and the quality of construction. All these factors are highly variable with local conditions. Because of such complex and site-specific relation between lining performance, it would be highly beneficial to under-

4. Canal lining is thought to be synonymous with modernisation, and is predicated on minimising seepage losses. The principle benefit of lining in many cases is to increase channel capacity, although lining existing sections without re-modelling may not always solve capacity constraints in typical main canals.

take a comprehensive monitoring program including several typical set of local conditions that would enable engineers to draw objective conclusions as to the performance of lining under various conditions.

The conditions of irrigated agriculture in the RRD and the rest of Vietnam will be subject to changes resulting from changes in the country's economy. As farmers become more exposed to the forces of market economy, the profitability of farming will require larger and more efficient farming units. Such farm units are likely to need an increasing level of mechanisation, a phenomenon that has also occurred in other Asian countries. These changes in the farming structure will require a different layout and type of irrigation service, which must be served by a more flexible type of irrigation infrastructure. These long-term changes must be taken into account in the formulation of an asset-management program.

Institutional development

Considerable effort was made to understand the institutional landscape at the start of Project 9404 (ACIAR 1999). The first hurdle was to provide evidence of the need for increased farmer participation in irrigation system operation and management, which came out of the socioeconomic and diagnostic surveys, and the performance assessment using IMSOP.

The next stage was to 'evolve' an acceptable model for increased farmer participation that conformed to existing legislation and the lack of legal provisions for private entities. The first Asian Development Bank Water Resources Sector loan included two pilot water user associations outside the Red River Delta at Song Chu and North Nghe An in 1996–1997. These organisations were set up where the commune/HTX system had broken down, and were constituted under the Law on Cooperatives of 1996, which later became the springboard for the reform and 'revitalisation' of the cooperative system in 1998–1999.

Project 9404 proceeded with the formation of three water-user advisory committees (WUACs) to liaise between multiple communes on a secondary channel and the irrigation company—with the close cooperation of the local irrigation management station belonging to the company. This was envisaged as an interim step to forming a more autonomous umbrella organisation as a water user cooperative under the provisions of the 1996 Cooperative Law (see Figure 7).

Two WUACs were established in 1998 at the two largest secondary canals (N1 and N5) near the main pumping station at La Khe, and a third for all secondary channels serviced by the fourth and last cross regulator in the main channel. There is one large secondary channel supplying three communes at this site, called N13, and the WUAC has taken this name.

The WUAC at N1 has effectively failed, despite being reformed a number of times. This was a result of internal conflict between village and Ha Dong Town–based communes, specifically over access to water for commercial fishponds. The WUAC at N5 has proved to be very successful, under strong leadership from the vice-chairman of one of the member communes, and has become the focus for further development into an autonomous water user association. Flow monitoring records show considerable reductions in water diversion at N5 (supply ratio of 0.95–1.05), while members claim considerable improvements in internal distribution, and larger areas commanded by gravity, resulting in lower costs of water supply through reduced secondary pumping higher and reduced production costs.

N5 was given approval to become a formal organisation by Ha Tay Province in April 2001, after a long and detailed process of negotiation between the Provincial Agriculture and Rural Development Service, LKIS, the project and the WUAC itself. The WUAC has been very proactive in seeking to become an autonomous self-funding organisation. In the interim, it developed the required rules of association, communications and water distribution to be a fully functional but not self-financing organisation. A seven-stage process of investigation was undertaken to register and classify all land and landholders accurately within the 900 ha command area and to negotiate full approval and commitment by all 6-member communes.

At the same time, attempts were made to scale-up the N5 experience to N1 and N13, and begin new umbrella associations at N3 and N5a. This met with mixed results, due to company inertia and a cautious provincial administration on the one hand and keen members at N5 and N13 on the other. A major concern at N13 was that the local irrigation station staff would lose their jobs and be reallocated, and there is evidence that extra payments for preferential service are routinely extracted from farmers by irrigation sub-station staff. The restitution of subsidies and limited external pressure or incentive from the centre has not obliged the province to be anything but cautious in approaching devolution of irrigation management.

The village level cooperatives stand to be the biggest losers in this change in institutional arrangements, since water fees will be collected and processed by the water users' association (WUA). This potential loss of income and influence by communes has been overcome at N5, but is significant at N1, and more experience is required to see how the three full organisations perform. At present there are no satisfactory independent procedures for dispute resolution and neither are they expected in the short term.

Costing and Pricing of Irrigation and Drainage Services

The provision of a sustainable irrigation and drainage service at La Khe is compromised by the gap between the actual cost of service provision and the level of revenues from water fee collection. The cost calcu-

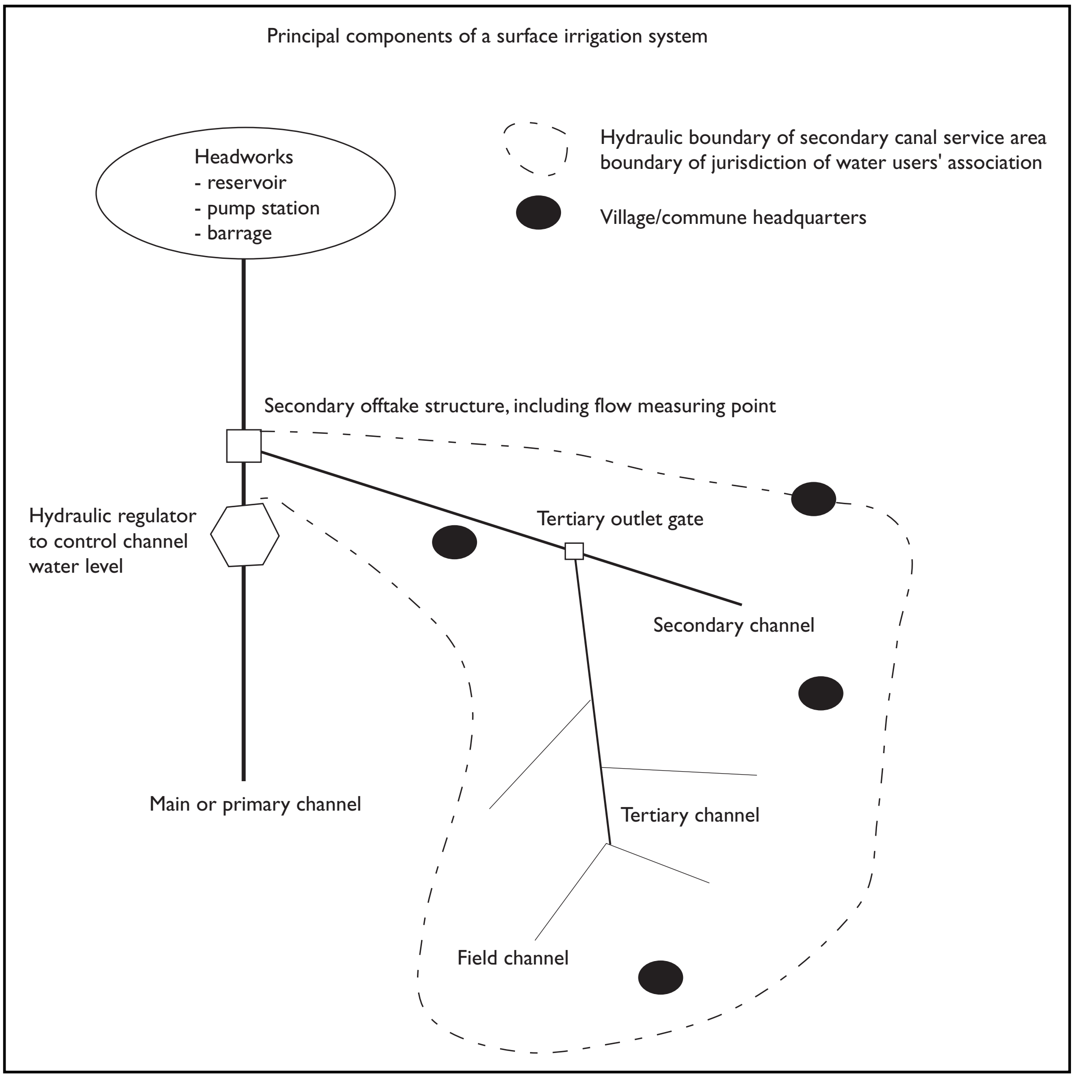

Figure 7. Schematic diagram of the irrigation system and institutional arrangements.

lated on the basis of renewal accounting is US$52.00/ha, which when compared with the current water price of US$40.00/ha, leads to a shortfall of US$12.00/ha.

The current level of water fee represents about 6.5% of average annual rice yield at La Khe. These figures are based on the assumption of 100% collection of the water fee. The actual rate of water fee collection, however, is lower, ranging between 63% in 1994 and 88% in 1996. The more obvious result of the gap between cost and pricing is the deterioration of the irrigation and drainage infrastructure as a result of the DEs inability to carry out the necessary maintenance and repairs of the system.

Attempting to ascertain the impact of an increase of US$12.00/ha on the existing farmers' ability to pay for irrigation and drainage services is difficult. If the impact of a US$12.00/ha increase in the price of water on the farmers' incomes and their ability to pay for it is contrasted with the household survey study, then the impact is negligible for the best performing enterprises with incomes over US$5,000/ha/annum, as shown in Figure 8. For enterprises with incomes between $200/ha/annum and US$1500/ha/annum (45% of households surveyed) the increase in irrigation service represents 7% and 0.9%, respectively, whereas for the bottom 23% of the households it becomes more significant (Malano 1998).

In an attempt to forge a stronger link between service and payment, the project has been trying to implement a pilot volumetric charging study at N5, where the WUA has also shown strong interest in the idea.

Volumetric charging

Under the proposed institutional arrangements, the WUA will be responsible for ordering water from the LKIS and reaching agreement on a irrigation plan at the start of each season. The LKIS will supply water to the WUA at the secondary canal offtake on the main canal under the ordering and scheduling arrangements agreed upon by the two parties.

The WUA will retail water to its members according to an agreed schedule. This arrangement will require the LKIS to measure the water sold to the WUA at the secondary offtake that will be later used in the calculation of the volume-based cost component.

The proposed fee structure includes two elements: (a) a volumetric irrigation fee, which will be proportional to the electricity used for pumping irrigation water; and (b) an area irrigation fee, which will be based on the area of land that can be irrigated from each secondary canal. This part of the cost will account for the fixed water supply costs such as maintenance, administration and asset annuity.

Currently, the La Khe Company supplies water with a differential level of service that includes full gravity, part-gravity and non-gravity. This variable level of service is reflected in the fee level charged to farmers. The proposed two-tier principle for water charging could initially be implemented by:

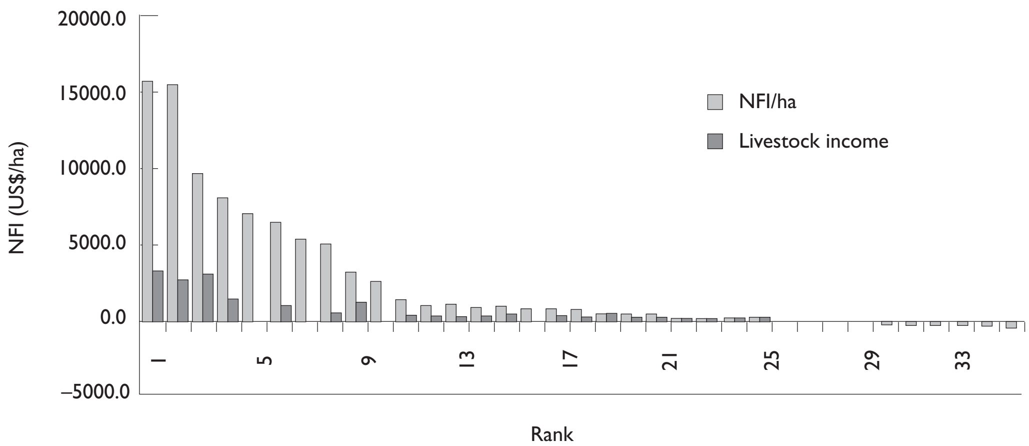

Figure 8. Income distribution at la Khe, 1998. Net farm income (NFI)/ha including livestock income.

- assessing the volumetric component of the fee according to the electricity consumption, and the area-based component of the fee according to all the other company fixed costs; and
- ensuring that, in the initial stages of the change over, the combined volumetric and fixed components of the charge remain at the same level as the traditional water fee.

An example of the application of the proposed fee structure follows for the 1999 financial year, which includes the spring and summer season. No charges are levied for supply during the winter season.

Table 3 shows the current fee structure charged by the LKIS. The area water fee to be charged to farmers on the secondary canals should equal the traditional water fee, less the estimated average cost of electricity for pumping irrigation water. A valuation of VND1500/kg rice was assumed in the calculations based on 1998 prices, although more recently the price of rice has fallen to about VND1200/kg.

These figures were discounted by the estimated average cost for irrigation pumping inflation adjusted at 1998 level, which for the whole of La Khe totalled VND1,145,756,662. The average electricity cost per sao (1 ha = 27.7 sao) assuming a total irrigated area of 8796 ha is VND4,703.

Table 3. Traditional fee structure according to level of service at La Khe.

Type of irrigation service	Spring season VND/sao	Summer season VND/sao
Gravity	16,245	13,538
Part-gravity	11,372	9,476
Non-gravity	8,123	6,769

[a] 1 ha = 27.7 sao.

Table 4 shows the new schedule of area-based water charges, calculated for 1999. These figures resulted from the deduction of VND4,703 from the original figures in Table 3.

The volumetric irrigation water fee should be charged to the WUA after each irrigation season, including the winter cropping season, to recover the cost of electricity for irrigation water pumping. The WUA should allocate this fee amongst all the farmers according to the area of land irrigated by them. Farmers must be told that, while the fixed fee will be reduced by 3.1 kg rice per sao, there will be an additional volumetric fee charged averaging VND4,703 (or 3.1 kg of rice) per sao to be collected for the La Khe company. The actual amount of the volumetric charge, however, will depend on how much water is actually used.

Table 4. Revised area-based charges in 2-part tariff.

Type of irrigation service	Spring season VND/sao	Summer season VND/sao
Gravity	11,542	8,835
Part-gravity	6,669	4,773
Non-gravity	3,420	2,066

[a] 1 ha = 27.7 sao.

Based on pump monitoring data (ACIAR 1999) it has been estimated that the main pumping system delivers 40.00 m^3 per kWh of electricity. Using the cost of electricity in 1998 of VND560/kWh, the charge per cubic metre of water delivered is calculated as follows:

$$CUW = \frac{EC}{CKW \quad E_c}$$

where

CUW = cost per cubic metre of water delivered;

EC = electricity cost per kWh

CKW = cubic metres per kWh delivered at the pump site; and

E_c = estimated conveyance efficiency factor, to account for average system losses in main canal.

Assuming a conveyance efficiency of the main canal E_c = 70%, the cost per cubic metre of water is VND20.

Table 5 shows the summary of calculations of volumetric charges for secondary canal N5. As explained above, this canal is currently being use to pilot new institutional arrangements at La Khe which are considered a prerequisite for the application of the proposed tariff structure.

Table 5. Calculation of volumetric charges for secondary channel N5.

Electricity cost (VND) per kWh (in 1998)	560
Average volume of water used (m^3)	81,811,355
Average electricity used for Irrigation (kWh)	2,045,994
Volume pumped per kWh from main pumping station (m^3/kWh)	40.00
Total irrigated area for La Khe (ha)	8,796
Total irrigated area in N5 (ha)	798
Average cost (VND) per m^3 at main pumping station	14.0
Canal conveyance efficiency factor	70%
Average cost (VND) of water delivered to secondary canals	20.0

An important aspect of this formulation is the ratio of the volumetric to the area-based fee. The current formulation assumes the inclusion of a volumetric component based on the cost of electricity, which represents approximately 30% of the total cost of operation of the asset annuity. A greater volumetric price component would send a better signal to encourage more efficient use of water and improve equity between those that under-use and those than over-use the resource. At this level of the volumetric tier, those who considerably more water than they need (say 200%) will have an small incentive to reduce consumption, but those who are under-supplied still have to pay an excessive amount for poor service. Nevertheless, the initial aim is to introduce the principle and follow it up by a progressive increase in the proportion of the charge that is volumetric and variable. There is some risk for the irrigation company in pursuing an increase in the volume-based component, in that it may lead to a significant reduction in income in very wet years where the irrigation demand is lower and a concurrent increase in drainage costs. Further analysis based on long-term climate variability would be needed to arrive at an optimum ratio between volume-based and area-based charge. The formula also needs to factor in the costs of operating the WUA to manage water distribution, and assess the risk in balancing volumetric and fixed components of that fee as well.

Management and infrastructure implications of volumetric charging

The ability to measure water is critical to the success of any volume-based water charging policy and, in theory, any water control structure can be used to measure water if adequately rated: existing offtake structures are being monitored twice daily at La Khe and three times a day at Dan Hoai, as part of the modelling and performance assessment program.

In practice, the monitoring effort and skill level required to carry out this task may currently be beyond that of many irrigation companies, but some alternative approaches are possible. In China, for instance, the duration of flow is substituted for actual flow measurement and relies on the assumption that design discharge is provided. The measuring points are rated roughly twice per year to give users confidence, and if design discharge is not routinely achieved, the water user associations can negotiate with the company. While this is not perfect, it has provided the basis for a successful arranged demand service in may irrigation systems in China with significant benefits in the improvement of water productivity.

There needs to be mutual belief in the accuracy of flow measurement—for N5 at La Khe, it has been suggested that both the WUA and the irrigation substation keep separate flow records, which can be compared with automatic flow monitoring to establish this mutual trust.

Implementing a volume-based charging policy will require an upgrade in the operational rules and capacity to enforce them. The company needs to be able to ensure supply at requested or scheduled start-up times and it needs to be able to enforce timely compliance by customers with start-up and finishing schedules. This is perhaps the main stumbling block in the short and medium terms to implement the policy at La Khe and most other systems in Vietnam, as it requires improvement to infrastructure as well as improved management skill (Malano et al. 1999).

Improving the scheduling of supply (particularly the specification of start and finish times) requires improved quantification of demand, which can be achieved either through (a) improved modelling, incorporating improved estimates of area and crop pattern or (b) by direct orders from the WUA. The latter is preferable, and WUA assessment of demand could even be facilitated by modelling, taking advantage of better knowledge of local conditions, crop pattern and crop areas to calculate more realistic demand. The modelling framework currently available at the irrigation company could also be used to generate the demand information for the WUA.

Perhaps the major hurdle to widespread improvements in water management (through improved management systems and economically responsive charging mechanisms) is management skill. Company management and operational staff would need to develop a clear understanding of the operational objectives and mechanisms to implement them throughout the system. This would require a rigorous training program to achieve the management quantum leap required to implement such policy. The same point is true if we consider the skills available within a WUA that now finds itself with the responsibility for managing a whole secondary canal.

Conclusion

The paper begins with a general introduction to irrigation and drainage in Vietnam, a country that is undergoing rapid economic and administrative change. National policy on water reform is incoherent and not strongly articulated from the top. At the same time, many reforms in Vietnam begin at the provincial level where there is sufficient interest and motivation to take action and generate a local 'policy', which may or may not coincide with that of central government.

The paper then looks in detail at the steps taken at one irrigation company to implement an improved management package, develop a blueprint for improved technology and resolve the associated institutional issues. The path of internal reform is gradual and complex. It has many interlinking details that should ideally be addressed in the broader policy framework in order to translate objectives into action.

The paper also highlights the technical and management improvements that are necessary for the successful implementation of operational, institutional and policy changes, especially in relation to more efficient pricing of irrigation and drainage services

A more proactive and uncompromising policy by the state would still need to consider the same issues and details of the balance of success and failure if policy changes are to be efficient and, in the long-term, beneficial.

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Water Resources Management in Vietnam and the Need for Change in Water Fee Policy

Nguyen Viet Chien*

Abstract

Vietnam has more than 2,000 rivers, 9 of which are large river systems with catchment areas over 10,000 km^2. On average, total annual flow discharge is over 800 billion m^3, of which 300 billion m^3 is generated in the country and 500 billion m^3 comes from outside the country. Rainfall in Vietnam is very uneven over space and time, and this is the most critical cause of many water-related problems: flooding and waterlogging in rainy season and drought in the dry season. As Vietnam is experiencing rapid change which is greatly impacting the use of its natural resources, there are many changes need in the water sector. This paper explores the challenges in the water resources sector in Vietnam, including the issue of water pricing.

VIETNAM has more than 2,000 rivers, 9 of which are large river systems with catchment areas over 10,000 km^2. On average, total annual flow discharge is over 800 billion m^3, of which 300 billion m^3 is generated in the country and 500 billion m^3 comes from outside the country. The characteristics of the main river systems in Vietnam are given in Table 1.

Rainfall is distributed unevenly in term of location and time of year. Statistical data show that 70–75% of annual rainfall occurs in 3–4 months (June–October) and, in contrast, in the three driest months (December– February) the rainfall comprises only 5–8% of the annual figure. Annual rainfall varies from 1,200 mm to 4,000 mm between regions. This uneven distribution of rainfall over time and space is the most critical cause of many water-related problems: flooding and waterlogging in rainy season and drought in the dry season. The Government of Vietnam has paid a great deal of attention to the management and development of water resources as a key natural resource, of which the agriculture sector is the biggest user.

For the development of water resources, the government has allocated a high percentage of the annual budget for the construction of infrastructure, including reservoirs, dams, pumping stations, and irrigation networks. At present, for the purpose of agricultural development, there are about 180 irrigation companies with some 20,000 staff. The responsibilities of these companies include the management of existing infrastructure to ensure irrigation for 3 million ha of cultivated land; and drainage of summer crop for 1.6 million ha of natural land in northern part of Vietnam. They are also responsible for maintaining infrastructure aimed at preventing salinity for 0.7 ha in the coastal range and the improvement of about 1.6 million ha of acid sulfate land in the Mekong Delta. Irrigation and drainage is widely recognised in Vietnam as the first important factor for agricultural development and the alleviation of poverty.

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Table 1. Statistics on the nine large river systems of Vietnam.

River name	Total catchment area (km^2)	Catchment area in Vietnam (km^2)	Percentage of country's natural area (%)	VN population living in the area (million)
Mekong	795,000	39,000	12.0	15
Dong Nai	35,000	29,700	10.0	10
Srepok	30,000	18,200	5.6	>1
Thu Bon	10,500	10,500	3.2	<1
Ba River	14,000	14,000	4.2	1
Ma River	28,400	17,800	5.5	3
Ca River	28,000	17,700	5.5	3
Red River	169,000	87,400	27.0	17
Ky Cung	–	11,200	3.4	1.02

Challenges in the Water Resources Sector in Vietnam

There are five key challenges facing the water resources sector in Vietnam:

1. Demands for water in various sectors will increase in term of quality and quantity, as a result of economic growth and implementation of the government policy for industrialisation of the country. This means that water resources will need to be managed more effectively in order to balance supply and demand, while maintaining water quality.
2. Because of deforestation and severe climatic change over recent years, water control for sustainable development requires a great deal of effort to improve works in the water sector, especially in mitigation of flood damage and in environmental protection.
3. There is a lack of clarity in the roles and responsibilities of the public agencies that plan and manage the country's water resources in the rapidly changing institutional, especially to implement the new water resources law issued in 1998.
4. Current water management at irrigation and drainage management companies is very poor, which is the most important reason that the efficiency of irrigation and drainage systems is very low, on average 50–60% of the design capacity. Many irrigation and drainage systems are old and badly deteriorated. They need to upgraded and rehabilitated in both physical infrastructure and management skill.
5. Existing irrigation and drainage systems need to change to meet the requirement for national cropping diversification.

Water Prices in Vietnam

As mentioned above, there are many problems in management of irrigation and drainage systems that lead to quick deterioration of such infrastructures. A big problem is the lack of funds to maintain proper operations and maintenance. Annually, the funds meet only around 50% of the required investment for improvement of the dyke systems, 60% of that for improvement, operation, and maintenance of the irrigation schemes, and 45% of domestic water supply and sanitation. Irrigation and drainage companies are considered to be public business companies which obtain their fund for running the systems from the following sources: local water fees, subsidies from government for drainage in very severe climatic years and for large repairs and rehabilitation; and charges for other services. From the above-mentioned financial sources, water fees are the biggest contributor and in many cases are the only source of funds.

Currently, the Government Decree 112 issued in 1984 defines the water fee for irrigation and drainage services. Following this decree, the water fee is being collected based on irrigated area at a rate that ranges from 4 to 8% of the local value of agricultural production. Experience has shown that there are many problems in implementation of the current water fee policy, including:

- The percentage of water fees collected is very low, on average, only about 50% of planned revenue,

which makes it difficult for the irrigation and drainage management companies to balance its annual budget to maintain normal maintenance of the infrastructure. The water fee is often withheld by communes, to be used for other purposes.
- The rate at which the water fee is levied is defined differently in different provinces and is usually lower than the rate recommended in the decree (normally at 2–5% of actual agricultural production).
- Lack of power to encourage farmers to use water in an efficient way.
- There is an unfair charge to farmers, because the water fee is collected on the basis of irrigated area, with no charge to those people who are not farmers but nevertheless benefit from drainage of the irrigation and drainage systems.
- The rate at which water is charged for non-irrigation services, such as aquaculture, domestic and industrial supply, is very low.
- The terms under which the government provides subsidies are not clearly specified.

The Government of Vietnam is implementing a program of upgrading and modernisation of irrigation and drainage systems at a cost of some hundred of millions of US dollars. It is now widely recognised that the upgrade of physical structure must be accompanied by an improvement in the management system in which the improvement of water fee policy is a key component. This is because the current water fee is based on a government decree issued at the time when the country's economy was a centrally planned mechanism that is no longer suitable in the new, market-based economy.

There is much discussion about water prices in Vietnam, but up to now there are no improved options successful enough to be approved by the Government to replace the decree 112-based water-charging policy. Therefore, in future this topic should continue to be researched on. International experience in this area would be very useful for developing new water price policy.

The new water pricing system must develop in a way such that all beneficiaries of the services provided by the government in managing the water resources of the Basin should be responsible to pay the real cost of the service, not just a fee. Therefore, in developing the new water pricing policy in Vietnam, there are some critical factors should be considered:

- Water must be considered as a good, and the cost of water-related services must reflect real value that may give irrigation and drainage companies sufficient funds to recover running costs and fund further development.
- All water users must pay water charges. In the case where a water user does not pay for the service, the irrigation and drainage company may have the right to refuse the service (currently the company does not have right to stop providing services, even to a farmer who has long record debt).
- With regard to the subsidy, the government must clarify the detailed conditions, then those farmer who have a right to have such subsidies will pay less than the true water price, and the irrigation and drainage company may receive subsidies directly from the annual national budget.
- The new water price must have a positive impact on saving water.
- In specific years of severe crop losses, the government must provide a special waiver of fees to reduce financial hardship.

Conclusion

Vietnam is a nation experiencing rapid change, which is greatly impacting the use of its natural resources—particularly land and water. There are many changes needed in the water sector; some are currently underway. Development of the water price is one of the important aspects that needs consideration.

For the past 6 years, with support from ACIAR, integrated water management for irrigation systems has been to introduce into Vietnam by two research projects (LWR2/94/04 and LWR2/98/34). The findings from these projects are very useful for managers and policy-makers to help them understand, and improve the management of, irrigation systems. Water price is an important topic that has not yet been fully addressed.

Economic Tools for Water Demand Management in Thailand: Conventional Wisdom and the Real World

François Molle*

Abstract

This paper first examines a few axiomatic statements that are generally accepted as basic tenets of conventional wisdom on water management in Thailand, most particularly in the Chao Phraya River basin. The confrontation of these theoretical assertions with real-world observations shows that blueprints based on such rationales poorly fit the Thai technical, institutional and political context. Most arguments put forward to support the introduction of water charges or water markets are proven to be weak, flawed or unconvincing. In particular, water-use efficiency at the basin level is shown to be high and reflects how water management and access to water resources have been changing in the last two decades, as the basin has gradually closed. A scenario for working towards the definition of water rights and integrated management is outlined, but emphasis is placed on the wide gap existing between the prerequisites to such a reform and the current situation.

TO the layperson, a monsoonal tropical country is associated with the image of land made luxuriant with plentiful water. The stark reality, however, is that Thailand has joined the host of countries currently facing water shortages. With the exception of the southern region and some forest areas along the border, hydrologic data show that the yearly average rainfall in Thailand varies between 1100 and 1600 mm, (ESCAP 1991). A somewhat attenuated monsoon provides water in excess for about half of the year, while for the remainder of the year there is little rainfall and the only available water is that which is released from 28 storage dams. After World War II, Thailand's water resources were largely untamed and lacked storage capacity to regulate the seasonally contrasting water regime. The population was less than 18 million, and most of the uplands were still covered with forests. The second half of the century, however, would witness dramatic changes in population (62 million inhabitants by 2000), urbanisation (10 million people in the Bangkok Metropolitan Area [BMA]), water resources storage development (28 main dams comprising a volume of 66 billion m^3 [Bm^3]), cultivated area (52 to 130 million rai [1 rai _ 0.16 ha]) and irrigated area (32 million rai, or 25% of the total agricultural land). However, only 15% of the 200 Bm^3 annual run-off remains trapped in the dams (ESCAP 1991).

Gradually, through the concomitant development of irrigated and urban areas, constraints on water resources started to be felt, particularly in the Chao Phraya River basin, where irrigated areas have been developed beyond the potential defined by the available water resources. The expansion of BMA led to the gradual extraction of a significant share of the basin resources for urban and industrial water uses. Increasing competition for water materialised through recurrent water shortages, occurring principally in the dry season and mostly affecting rice cultivation, but also prompting restrictions in water supply for the capital (in 1994 and 1999). With gloomy prospects for the Thai water sector, we may distinguish four schools of thought which have emerged in response to the water challenges posed.

The first school of thought on water resources, promulgated by NGOs and social activists, considers water as a social good, the free use of which is a human right. As expressed by a scholar at Thammasat University 'natural resources—such as water—are essential to all, and should not be managed by market mechanisms. Otherwise, water would not flow by gravity but by purchasing power. Commodification

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of water should not be allowed because the right to natural resources is a basic right all human beings have'. This view is echoed by some farmers, who inquire why they should 'have to pay for the water that Mother earth and the forest give us' (Petipong calls for 'national agenda', The Nation, 11 June 2000).

A second viewpoint is spearheaded by international donors, notably the Asian Development Bank (ADB 2000), together with some segments of the public administration who, willingly or not, seem to have rallied to the cause. They have voiced support in favour of the introduction of economic incentives and demand management. Water savings, they argue, must come from water pricing (so that users will inevitably be encouraged to reduce their consumption), and improved management. Conflicts between users, in particular different economic sectors, are eventually best regulated by market-based mechanisms.

A third attitude, favoured by most of the Thai public sector, supports an administrative solution rather than one based on demand management. New laws aim at giving more control and power to the various administrative bodies concerned with water issues, orientations quite evident in the two drafts of the 'Water Law' which have been elaborated in recent years (Christensen and Boon-Long 1994). Emphasis is also placed on coordination between agencies and on the idea of basin agencies. The possibility of creating a Ministry of Water has also been debated for a few years.

Finally, the somewhat 'traditional' view put forth by technical bodies (and consultants) holds that the problem of water shortage can be solved by increasing supply through further water resource developments. These efforts include new dams and transbasin water transfers from the Salaween and Mekong rivers. This solution faces growing opposition from environmental activists and is loosing its attractiveness for donors because of the increasing costs of tapping each additional cubic metreof water. However, it tends to be preferred by some governmental agencies for well known reasons, ranging from the dominance of an engineer-oriented culture, to political and financial interests, both direct or indirect, to certain actors (Repetto 1986; Christensen and Boon-Long 1994).

While discussions on the opportunity to levy a water charge are an old story, the conflicting views presented above have recently been put in sharp relief. The issue entered the limelight following the announcement that the granting of ADB funds to the country (presented as being crucial to the country's economic recovery following the crisis) would be conditional on its subscribing to, and applying, the overall principle of water pricing. The public debate has been obfuscated by the different nature of the economic tools envisaged and of the arguments which can be raised in favour or against such policies. The conflicting, and often confusing, views on water charges appear clearly in newspapers articles, interviews, consultants' reports and NGO literature.[1] It has also been obscured by the recourse to a series of axiomatic statements, which tend to become common wisdom as they are repeated, and by the proposal of measures and policies of very general scope which may not have been sufficiently confronted to the 'real world', i.e. the Thai context as presented in this paper.

This paper focuses on proposals for water demand management in Thailand and first reviews a series of misconceptions that are commonly encountered. In the second part, proposals for reform of the irrigation sector are briefly outlined and examined in the light of some peculiarities of the Thai context. One of the difficulties for reform is to cover the wide range of social and ecological situations found in Thailand and, in particular, the necessary distinction between small and medium/large scale irrigation projects. The former is often epitomised by the traditional muang fay systems of northern Thailand, while the latter are best represented by the Chao Phraya Delta. Except as otherwise mentioned, what follows refers to medium/large scale projects, which make up two-thirds of the country's irrigated area. The reflection also centres on the dry season, when water scarcity is an issue, rather than on the rainy season.

Conventional Wisdom on Water Use and Other Widespread Fallacies

'Water greed', or farmers as 'guzzling' users

International agencies (and sometimes, in their footsteps, local officers) commonly report that farmers are 'guzzling' water or are showing 'water greed' (The Nation, n.d.). Based on common knowl-

1. An examination of official declarations reported in national newspapers gives a measure of the fluctuating argumentation, reflecting both the unsettled nature of the negotiations, the general nature of the arguments and the lack of consensus even within a given administrative body.

edge that efficiency in large state-run irrigated schemes is often found to be as low as 30%, there is a tendency to stick to this overall vision without questioning it any further. Yet, research conducted in recent years has shown that water basins tend to 'close' when demand builds up, and that little water is eventually 'lost' out of the system. There has been widespread recognition that focusing on relatively low water efficiency at the on-farm or secondary levels could be totally misleading (Keller et al. 1996; Molden and Sakthivadivel 1999; Perry 1999). When analysed at the macro and basin level, many systems—river deltas accounting for the most significant of them—are eventually found to operate with extremely high overall efficiency. Thus, the scale of analysis of water use efficiency is crucial.

The Chao Phraya Delta in the dry season provides the most illustrative example of such a closed system. Most of the return flow from fields or canals is re-used downstream and the majority of the drains have been gated in order to capture or retain superficial and sub-superficial flows in the dry season. Several tens of thousands of tube-wells have been dug to tap shallow aquifers. Water releases at Bhumipol and Sirikit dams, as well as in Chai Nat diversion dam, are nowadays attuned to user requirements and give way to little waste. If we consider the efficiency of irrigation at the macro level, we see that the only 'wastewater' (i.e. not used for production purposes) is water that evaporates from waterways or fallow land, or which eventually flows out of the delta system into the sea. As this flow is hardly sufficient to control pollution and salinity intrusion into the river's mouth (in the dry season), it follows that very little water is lost.[2] The second component of water loss is that of infiltration. Such a loss is channelled either to shallow or deep aquifers. In the first case, it is tapped again through tube-wells (forming secondary water sources) or soon returns to the drainage system where it is re-used. In the second case, it reaches aquifers which flow to the Bangkok area where they are notoriously over-exploited, resulting in land subsidence and horrendous costs for upgrading of flood protection and in flood damage.[3] We may therefore venture to state that infiltration losses in the delta are not sufficient to offset the depletion of the aquifers. A water balance of the basin (Molle et al. 2001a) shows that, in the dry season, the overall efficiency of controlled[4] water use in the basin is around 88%.

Even when we carefully examine plot irrigation, it is hard to find the decried pattern of wasteful practices. The main reason is that most farmers access water through pumping. This is true for all the farmers located in the lower delta (in this so-called flat conservation area, water is integrally and individually pumped from a dense network of waterways) and for approximately 60% of the farmers in the upper delta. Altogether, it follows that about 80% of farmers are resorting to pumping, the great majority using low-lift axial pumps. Although the Chao Phraya and Mae Klong schemes were designed to supply water by gravity, RID experienced difficulties in managing reduced flows in the dry season. To offset this constraint, farmers have, over the years, developed an impressive individual pumping capacity allowing them to tap whatever little flow might appear in the canal. It follows that, because of the costs incurred by these water-lifting operations, there is little likelihood that farmers may be squandering water.[5] This is consistent with recent estimates of water use in the delta, which also show that efficiency is remarkably high (60%), with only 1500 m^3 used per rai, including rainfall (Molle et al. 2001a).

More generally, what has often escaped the attention of many commentators is that such actors in the system have not been indifferent to growing water scarcity. On the contrary, they have been extremely responsive in recent times and have gradually developed flexible ways to access water in all places where it can be found. Currently, few conventional gravity systems are functioning as they have been designed

2. In past years, EGAT may have released water only for the purpose of energy generation, thus resulting in freshwater being lost to the sea. However, this has been extremely rare in the last 10 years during the dry season. Whether this should still be permitted by EGAT, even in the wet season, is discussed in Molle et al. (2001a). In all cases, such losses are controlled and deliberate, and therefore cannot be considered as reducing efficiency.

3. It is estimated that the cost of the damage of the 1995 flood amounted to 50 billion baht, that is, US$2 billion!

4. Includes water released from the dams, diverted from The Mae Klong basin and extracted from shallow and deep wells.

5. In some cases, the costs of pumping may even discourage farmers to grow a second (or third) crop. These costs, combined with poor levelling, also explain the low use of water in sugarcane cultivation.

Box 1. Water allocation in the Chao Phraya Basin.

The Chao Phraya Basin can be conveniently divided into three parts. The upper part (upstream of the two main storage dams: Bhumipol and Sirikit dams), the middle part (from the dams to Chai Nat), and the lower part, or the Delta proper. The dams are operated by the Energy Generation Authority of Thailand (EGAT). In the dry season, depending on the year, between 2 and 8 billion m^3 are released to be distributed by the Royal Irrigation Department (RID) among 25 sub-units called 'Irrigation Projects'.
Water goes in priority to Bangkok, then to the control of saline intrusion, the supply of orchards and shrimp ponds, and last to inland transportation and rice cultivation. While, in the past, EGAT could manage some slack and release water in excess of these uses, it can now afford it only in emergency cases. Thus, the irrigation sector, despite receiving the largest share on average, has to cope with a high interannual fluctuation of the amount of water apportioned to it. Allocation is a top-down process where the shares of the Projects are centrally defined. Water abstraction in the middle basin cannot be fully controlled by RID and has been increasing dramatically (to 35% of dams releases).

Figure 1. The Chao Phraya Basin, Thailand.

to. Considering this evidence, it appears that harking back to the picture of the farmer as a wasteful villain is thoroughly flawed, unfair, and at the least misleading in terms the debate under consideration here.

Poor efficiency generates water shortages

The idea that shortages are due to poor efficiency is another misleading and enduring misconception. Because it is believed that the efficiency of use is low (which itself is incorrect), water is supposed to be lost and some users end up lacking water. This is wrong not only on a purely hydrologic basis but also because it fails to understand the nature of shortages: the amount of water released for dry-season cropping is adjusted according to the changing water stock in the dams, while all other requirements are supposed to be met. When a shortage occurs, it is because cropping areas have expanded in an uncontrolled manner beyond what is possible to irrigate; or because insufficient carryover stocks have been kept in the dams and a succession of exceptionally dry seasons depletes water reserves beyond what is necessary to meet minimum needs. Such shortages are therefore caused by management failures and not by the lack of water per se. These failures are due to insufficient control, in terms of: (a) hydraulic facilities; (b) land-use planning in terms of cropping areas; and (c) political interference. Altogether, this results in poor scheduling. The shortage in itself is also independent of whether it has been possible to irrigate, say 2–3 million rai in the

Delta with the water released. Even with better efficiency, demand would remain far above supply, especially in years of drought when pressure on water is highest.

Farmers waste water because it's free…

The third main misconception is generated by juxtaposing the alleged water wastage and the fact that water is free, as typified by the refrain 'water is consistently undervalued, and as a result is chronically overused' (Postel 1992). This is echoed in Thailand by many observers[6] (e.g. Christensen and Boon-Long 1994) who believe that 'since water is not appropriately priced, it is used inefficiently, and consumers have no incentive to economise'.

Asserting that farmers in the Central Plain have never paid for the irrigation system or for water use is true only in a narrow sense. If we consider the revenues siphoned by the State from rice cultivation through the mechanism of the rice premium between 1952 and 1984, it becomes clear that rice farmers have indirectly paid back more than it could ever be dreamt of levying through a water fee. Indirect taxation through the control of market prices, export taxes, or exchange rates often significantly accrues to the government revenue as, for example, in Egypt or in Vietnam.

On the other hand, deficiencies in water management have compelled farmers to make considerable investments in pumping devices in order to access water. This, together with the corresponding operational costs, is a financial burden for farmers and shows that usually 'they don't get it free'. Field observations show that, in some cases, farmers may even resort to up to 3 or 4 successive pumping operations, from a remote drain, 'step-by-step' up to their plot! Even in the western part of the delta, which is irrigated by a more modern system constructed on the Mae Klong river and is part of an opened water basin, studies of water use at plot level have shown that conjunctive use and pumping are widespread (Molle et al. 1998). In addition, the same case study has shown that half of the investments on-farm had been done by the farmers. This is enough to invert the statement considered here: most farmers pay to access water because they have to pump it onto their fields; in order to limit their expenditures they pay great attention to not use water in excess.[7]

… therefore pricing water would lead to water savings

Despite no logical evidence,[8] the reciprocal of the above statement leads some to assert that pricing water would lead to significant water savings. This seems to be taken as indisputable fact and is incorporated even in official declarations.[9] It is already apparent that this constitutes an abusive extrapolation of what may apply to domestic and industrial main water use. The main mechanism of such economic regulation is the capacity to charge water use volumetrically, which is beyond consideration for the

6. 'Currently, most farmers don't have to pay for irrigation water and, *thus, have little incentive to conserve water or to use it efficiently on high-value crops.* As a result, irrigation efficiency is under 30%' (TDRI 1990; emphasis added).

7. And even if they don't, such as can often be observed in the Mae Klong irrigation system, it is because the system is still 'open' (supply exceeds demand) and this is of little consequence. In addition, return flows are re-used downstream (those of the Mae Klong are used to supply the West Bank) and there is no scope for water saving at the macro scale.

8. Formally, it does not follow from 'A implies B' that 'non-A implies non-B'.

9. The weight of common wisdom can be sensed from the fact that the DG of RID himself recently acknowledged on a national TV channel that irrigation efficiency is low in Thailand (30%). Note also the declarations of an official of the Ministry of Agriculture: 'Water should be priced in order to increase the efficiency of its use in the farm sector' (Groups against farmers paying to use water, The Nation, 21 April 2000); 'Agricultural experts agree that water-pricing measures would help improve efficiency in water use among farmers' (Government to consider ADB terms, The Nation, 17 Feb. 1999); the Director of the National Water Resources Committee: 'In reality water is scarce, and the only mechanism to save water and encourage efficient use is to give it a price' (Water-pricing test project to start soon, The Nation, 23 April 2000); the resident advisor for the ADB in Thailand: 'International best practices suggest that efficiency in water management can be improved considerably through imposition of nominal water user fees' (Farmers say no to water burden, Bangkok Post, 11 June 2000). 'Currently, most farmers don't have to pay for irrigation water and, thus, have little incentive to conserve water or to use it efficiently on high-value crops. As a result, irrigation efficiency is under 30%' (TDRI 1990) etc.

context of smallholders in gravity schemes with poor regulation facilities. Therefore, the only change in behaviour which can be expected is that of farmers using more water, because they will tend to think that by paying for it they are entitled to fully use it (Moore 1989). Volumetric wholesaling to groups can be an option, but prerequisites are huge, as will be discussed in the second part of this paper.

In any case, it is the very principle and objective of achieving water savings in the agricultural sector which may be a nonsense. Real water savings per rai can come only from the reduction of soil/crop evaporation; that is from the adoption of non-rice crops (or from micro-irrigation) (discussed later). Other interventions on current cropping patterns may only disturb the 'water chain' which links superficial and underground water use at different locations of the basin.[10]

Water needs to be reallocated to economically more beneficial uses

Another conspicuous and widespread argument is that centralised water allocation in Thailand has reached its limits and that water rights and a water market would provide a flexible mechanism to allow the reallocation of scarce resources towards the most economically profitable uses. This is strongly reminiscent of the deadlock experienced in the western US, where water rights[11] are locked into uses of low-productivity and where market mechanisms constitute one of the ways out of the stalemate (see Huffaker et al. 2000). The claim that central agencies have failed in properly allocating water has become a refrain supporting the idea of markets as an alternative.

In the Thai context, commentators do not hesitate to incorporate this concern into their rationale, asserting that the State has proven inefficient in centrally allocating water to the most beneficial uses.[12] It is intriguing to see the ubiquity of this argument, even outside its 'original' context, and how it permeates debates even in settings where this problem has been handled relatively successfully. Contrary to the alleged government failure in allocating water resources, sectoral allocation in Thailand has been driven by a clear priority in use, which mirrors the economic return of all activities. Cases of industries with activities that would have been constrained or impeded by the lack of water are unheard of and it's hard to see how criticism of central allocation can fly in the face of such evidence. The deadlock experienced in western US is unknown here and establishing a water market might create exactly the kind of problems it is assumed to solve, should, as is apparent in the US, the rural sector be reluctant to relinquish its established right.

Central allocation may appear as a problem to farmers, who are effectively gradually dispossessed of their 'unwritten' right as other uses grow, but is not a problem to other economic sectors which are served at low or no cost[13] and in priority.

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10. See the example of the Snake River, in which such improvement eventually proved adverse by drying up the water used by use-dependent appropriators (Huffaker et al. 2000). More generally, Keller et al. (1996) have shown how 'attempts to increase irrigation efficiency at the micro level often lead to reduced irrigation efficiency at the macro level'.

11. There is some irony in the evidence that, if the Thai legal system had been based on prior-appropriation rights, like in the western US, the Delta would have been granted senior rights on water since the 1960s or earlier and Bangkok would now be trying to buy these rights from farmers. *In such a case, farmers would at present not be being asked to pay but, on the contrary, would be being courted to accept money as compensation!*

12. A typical example is provided by Christensen and Boon-Long (1994): 'a concern which could raise problems in the area of basin management involves the authority of the basin authorities to impose allocation priorities… The burden of proof for such an initiative is to show that command and control could result in better allocations and less market failure'. Israngkura (2000), for his part, considers that 'the returns on the irrigation dam investment have been low due to the lack of effective water demand management that could prevent less productive water utilisation'. This suggests that irrigation and its assumed low return has deprived other potentially more productive uses, whereas irrigation is in fact allocated the leftover in the system (after the prioritisation of water to BMA and energy production). TDRI (2001) posits that 'the current command and control system is unable to meet structural and cyclical changes in the demand and supply of natural resources, including water', while for Kraisoraphong (1995) 'Past experience has shown the government's role to be ineffective and thus an alternative proposed by economists and the academic circles has been to use economic instruments such as water pricing'.

13. Non-agricultural users pay for the cost of production (abstraction, treatment, transfer) but not for water itself.

Finally, there are practical considerations that relegate water transactions to the category of fancy mind-games. Re-allocation of water is difficult to achieve because it requires not only accurate definition of individual rights, but also a very high degree of control on water and transportation facilities required to transfer water from one user to the other. The assertion that 'if the price of rice is low, [Thai] farmers would be happy to cede their right to industrialists' (Wongbandit 1997), runs counter to the most basic evidence. Industrialists or cities are served first and would do nothing with more water attributed to them when the price of rice is low, let alone the fact that the physical constraints of the distribution network make such a reallocation impossible. How would the 'rights' of a group of farmers in, say, Kamphaeng Phet (middle basin) be transferred to a given golf course or factory in the suburbs of Bangkok?

Farmers get the 'lion's share' of water, despite their low economic return

The oft-repeated argument that farmers use 80% or more of water resources for irrigation is commonly used to suggest that the farmers' share is (1) too large, hence the shortage; (2) undeserved because the economic return per cubic metre is low; and (3) more vaguely, that if so much water is used, then efficiency must be low.

To present the agricultural sector as the spoilt, unrepentant and ungrateful child of the nation does little justice to the fact that farmers are in fact served with the (fluctuating) leftover water in the system. This share happens to be the largest one only because other uses have not yet developed to a wider magnitude (and also because the government has invested in infrastructures allowing the use of this water for irrigation). The argument glosses over the facts that (1) this share will decline in the future (as agriculture is usually deprived of its water when other sectors grow);[14] (2) the unwritten 'right' of farmers being limited to the leftover water, the farm sector has to cope with a very fluctuating supply, which also generates severe difficulties for management and for ensuring equity in allocation (see Molle et al. 2001a).

Rice farmers' water use is economically untenable and they should shift to field crops

Rice is admittedly a water-consuming crop. The possibility of achieving water conservation by inducing a shift away from rice to field crops, which consume approximately 40% of the amount of water needed for rice, has long been underlined by policy-makers and has formed the cornerstone of public projects aimed at fostering agricultural diversification (Siriluck and Kammeier 2000). This was already a recommendation of the FAO as early as the 1960s and is the alternative which 'received the most attention' in Small's (1972) study of the Delta. Australian and Japanese cooperation engaged in agronomic tests in the late 1960s and 1970s in order to propose field crops for irrigated areas. 'In recent years, low export prices for rice, and the difficulties encountered by Thailand in maintaining her export markets have further intensified the interest in stimulating the production of upland crops' (Small 1972). Such a statement, issued in 1972, has been a recurrent refrain for at least four decades.

Planting crops with lower water consumption would, ideally, allow more farmers to benefit from a second crop in the dry season. Evidence of the dynamics of diversification in the Delta (Kasetsart University and IRD 1996) shows that farmers display great responsiveness to market changes and opportunities (a point clearly evidenced by the recent spectacular development of inland shrimp farming [Szuster and Flaherty 2000]). Good transportation and communication networks allow marketing channels to perform efficiently. The main weak point remains the risk attached to the higher volatility of field crop prices, which discourages farmers from shifting significantly to non-rice crops. As long as the economic environment of field crop production remains unattractive and uncertain,[15] there is little incentive for farmers to adopt such crops and limited basis to sustain criticism of their growing rice, as

14. As experiences from Israel, United States, India or China indicate (Postel, 1992); in all cases agriculture's share was decreased to the benefit of cities.

15. It can be argued that rice marketing is also uncertain. However, the political sensitivity of rice production is such that there are limits that cannot be easily trespassed. In contrast, no one is really concerned (other than the farmers) if the price of chilli (a very intensive cash crop with heavy capital investment) swings from 30 to 2 baht/kg in one year and scattered growers have little means to voice their distress and limit their loss.

many have incurred losses by growing field crops (either by will or suggestion from extension services). Inducing shifts in cropping patterns to achieve water saving by means of differential taxes is believed to be unrealistic while such risk remains.

In addition, there are several other constraints (agro-ecology: heavy soil with little drainage, not favourable to growing field crops; labour[16] and capital requirements, skill-learning, development of proper marketing channels etc.), which characterise the process of diversification, and it is doubtful that, in addition to public policies aimed at fostering it, its pace may be increased much beyond what is already observed. Contrary to common rhetoric, farmers do not need to have their water priced to shift to other crops. They will increasingly do so if the uncertainty on water and prices is lowered. They have time after time shown dramatic responsiveness to constraints on other production factors, such as land and labour for example (Molle and Srijantr 1999), and have already sufficiently experienced the scarcity of water to adapt their cropping patterns, should conditions be favourable.

Thai taxpayers cannot pay any more for O&M costs and infrastructures

A declared objective of water pricing is its contribution to cost recovery, which can cover either the cost of infrastructure or that of the water supply. The first objective is not consistent with the Royal Irrigation Act of 1942 which makes it legally possible to charge users for water, but also stipulates that the money collected cannot be considered as state revenue and must constitute a special fund to be injected back into the improvement and maintenance of irrigation. Emphasis on investment cost-recovery appears misplaced when one considers the past indirect recovery through the rice premium and when one recalls that, even in the United States, recovery of public irrigation schemes is estimated at 4%. It also does not make clear, for example, how investments in irrigation differ from other social overhead or public investments. Such investments include those aimed at boosting economic activity as a whole (the government also creates industrial parks with infrastructures, invests in commercial fairs or tourism promotion campaigns, or in port facilities etc. favouring—or subsidising—other particular sectors of activity).

A water fee is more easily justified by the necessity to cover the cost of production of water. The alleged 'huge drain' that operation and management (O&M) expenditures impose on the national budget, however, amounts to only 0.16% of the national income and it would probably not be too difficult to find larger 'drains' whose plugging would have much less economic and social impact on the Thai population.

The argument of cost recovery can also be questioned within the context where taxation, subsidies, and government interventions are tools of a global policy based on antagonistic objectives. Schiff and Valdés (1992) showed how governments are caught up in a web of contradictory goals, including protecting farmers and protecting consumers from high food prices, and raising revenues through taxation and ensuring the competitiveness of economic sectors in the world market. Thailand appears in their study as a country where agriculture has been heavily taxed. This shows that, in the overall game, agriculture has been on the giving end rather than on the receiving end, which implies that the 'free water' subsidy can be seen as partial compensation for this situation.

Lastly, a water charge corresponds to an increase in production costs which cannot easily be passed to the consumer (because of the tight dependence of rice prices on the world market) and which, as a fixed tax, would raise economic risk in a context of relative instability of income (rice prices) and production (reliability of water supply).

Institutional Constraints and Opportunities for Water Reform

The different arguments questioned in the preceding section are often called upon to justify proposals for demand management or, more generally, for reform of the water sector. Unfortunately, they offer limited guidance in the Thai context and building reforms on weak tenets is not a good starting point. This section first outlines a possible option for a global reform of the irrigation sector, including participatory irrigation management (PIM), and then shows how the different components of reform are faced with major constraints that preclude over-enthusiasm and lead us to envisage changes occurring over the long term.

16. For example, the harvesting of mungbean, a typical supplementary crop with no additional water requirement, is often a problem because of labour shortage.

Baseline scenario for the definition of water rights

Because of the intricacies and complexity of small-scale rice farming in large, gravity-irrigation schemes, there is little scope to define individual water rights in such settings. Even levying a water fee per unit of land is doomed to face severe difficulties in situations where access to water is highly heterogeneous. This is the case, for example, in the upper delta, where some farmers may access water all year long while elsewhere others receive very uncertain supply. In addition, this access can be partly provided by gravity, partly through pumping, and their respective shares can vary greatly from year to other. Therefore, quantifying the real benefit of irrigation water for hundreds of thousands of farmers, when this benefit is highly heterogeneous in space and time, is deemed impracticable.

One must therefore turn to the alternative of 'water wholesaling' in which water is attributed to groups of users ['water management blocks' for TDRI (2001)], for example to those farmers who are served by the same lateral canal, on whom would fall the burden and the responsibility to allocate water, solve conflicts, and collect a water charge. What would be expected is that binding farmers together by granting them a collective right could be a way to 'force' them to act collectively in order to (a) achieve greater efficiency/equity within the command area of their canal; (b) to constitute a form of bargaining power to demand from RID the water supply they are entitled to; (c) to internally solve the problem of differentiated qualities of access to water and define individual charges accordingly; (d) to instil some formalised notion of water rights that could later be conducive to some form of tradability; (e) to constitute autonomous bodies that could take over a part of the managerial tasks attributed to RID and could further federate at the Project or basin level; and (f) to foster, in return, a corresponding improved performance on RID's (and EGAT's) part. The potential benefits are so sweeping that one might be tempted to gloss over the prerequisites to such moves.

We must first investigate what is meant by 'improved performance', what are the constraints experienced by RID and EGAT, both those which may lie beyond their jurisdiction, and those which offer significant possibility for progress. At the other extreme, it must be determined whether farmers are able or willing to respond as expected. Such an overall analysis, to be fair, would require much more space than available in this paper. Only a few points will be briefly mentioned here [for a full discussion on the issue, see Molle et al. (2001a,b)].

Water rights and water control

At the basin level, a first constraint is the coordination of dams management and irrigation supply. In the past 10 years, contrary to common criticism, the right of EGAT to release water in excess of users' requirements has not resulted in widespread water waste. Water allocation and distribution in the dry season are faced with two difficulties. The first one is the partial lack of control of RID on the system. This includes: (a) a growing uncontrolled water abstraction in the middle basin (representing up to 35% of releases from dams), which impacts on the water available for the delta; (b) a difficulty in ensuring proper hydraulic conveyance with low flows, and a low/fluctuating upstream water level at the Chai Nat diversion dam; and (c) a loss of control over the cropping calendars of farmers, who may use secondary water sources (e.g. groundwater pumps) to start planting crops which must later be supported by canal water. In order to deliver water with certainty, RID needs to increase control over the inflow at Chai Nat, at the apex of the delta. What must be stressed here is that regaining control over water use is far from being a problem of a purely technical nature. It goes together with identifying users and controlling their use, but it also goes with the setting and enforcement of institutional arrangements for sharing and managing water at the various levels applicable.[17]

Achieving equity in allocation is also made difficult by the fact that available water stocks (from storage dams) vary, for each dry-season, between 2 and 8 Bm^3. As a result, it has proven unsustainable to stick to the 'rotational' allocation policy established in the early 1980s in which half of each Project was to

17. Molle et al. (2001a) distinguish six different levels of water allocation in the Chao Phraya basin: (1) the basin level (upper, middle and lower basin); (2) the delta level (share of each main canal); (3) the main canal level (share of each Project along a given main (or trunk) canal); (4) the Project level (share of each lateral within the Project); (5) the Lateral level (share of the different canal reaches); and (6) the ditch level (farmers sharing water at the ditch level).

receive water one year out of two, because this 'right' could not be ensured. In some years, water was not sufficient, while in others, relatively abundant supplies triggered cultivation in larger non-target areas.

In short, it is far from certain that infrastructure and management skills would allow RID to significantly respond to a growing demand for better performance. Several sweeping technical and institutional improvements must be achieved beforehand and simultaneously.

Decentralisation of water resources management necessarily rests on increased participation of users: this takes us to the question of the participation of farmers—under what conditions it can be achieved and how it relates to the preceding reforms. The past experience of the failure of water user groups (WUG) shows there is no room for over-enthusiasm on this matter. Contrary to the *muang fay* systems in the upper part of the basin, there is no congruence between the hydraulic units and the administrative or social spatial units.[18] For large irrigated schemes, it is another matter. In the basin, these schemes are best known for the wide-scale failure of past attempts to set up WUGs. There are a number of anthropological and cultural considerations that can be raised to explain the perceived difference between the Central Plain and other regions, and the failure of these groups (Molle et al. 2001b). However, the failure can also be ascribed to the weakening of the exigency for collective maintenance of tertiaries (mechanical means are now available at low costs), the drastic strengthening of individual water-use strategies permitted by the spread of wells and of cheap, private and mobile pumping devices, and the irrelevance of pre-existing organisational patterns in a context of fluctuating inflow and uncertainty.

It is less than certain that the establishment of groups along hydraulic boundaries would be sufficient to ensure the homogeneity of strategies within them. Social groups are constituted by several interwoven collective networks (based on kinship, politics, administration, religion etc.) with different spatial spread, and are far from uniform, in particular regarding leadership. The possible reaction of head-enders, in particular, who are widely favoured under the prevailing conditions, brings in much uncertainty. Social cohesion has been weakened by the transformation of the village economy, where widespread pluri-activity and off-farm employment entails heterogeneities in the interests of villagers in agriculture, and in their willingness to commit to, or participate in, collective action. The 'wholesaling' of water to groups of farmers is tantamount to shifting the burden of quantitatively determining the benefit to the different individual farmers (i.e. the fee, the amount, together with its collection) to communities or groups supposed to be homogenous and responsive, after having 'their interest' defined for them.

An important consequence of the above difficulty is that the assumption that the hypothetical right attributed to a group of farmers could change each year blithely ignores the fact that this group will have to find a way to establish a socially acceptable allocation of water. It is not clear how the burden of achieving basic equity in a context where there is variation in the group's 'right' can be handled by farmers. This also applies to the collection of the water fee which may lead to widespread disagreements if all farmers do not receive the same standard of service (which is likely to occur if the water allotted serves only part of the group or if it tends to be less than expected or required). This shows that it is of paramount importance to establish allocation 'rights' which allow the full irrigation of the different hydraulic units and to have these rights assured. However, there is no simple solution to how such rights can be defined and activated in an equitable manner over the years, at the basin level and in a context of fluctuating water stocks in the dry season.

In practical terms, it still remains to be defined how such drastic changes could be brought into the system with the acceptance and participation of both farmers and agencies. The costs of establishing such a policy, defining sound allocation hydraulic units, involving farmers in the conception phase, coordinating uses at the basin level and reducing political interference, and controlling and applying penalties on unauthorised abstraction etc. are obviously huge. They require not only improved management skills and facilities, capacity building and deep institutional reforms, and improved enforcement capacity and political commitment, but also that these changes be

18. Even in the case of the People Irrigation Systems, the overlap is often only partial. *Muang fay* systems, in particular, often encompass more than one village. The observation made by Hunt (1989) that community-based irrigation often misleadingly serves as an underlying model for large-scale schemes is pertinent for the Thai case.

phased in, as an eventual success will be conditional on their concomitant establishment. The allocation of rights, responsibilities and risks between the different actors is crucial here. Who is inevitably accountable for the micro-allocation of water and fee collection cannot ensure adequate supply. This is an example of the devolution of responsibility for water supply services to organisations with limited power to influence the overall context.

Institutional and political settings

The measures outlined in the preceding discussion translate into crucial exigencies directed to the Thai institutional and political setting. The deadlock reflects the inadequacy of current laws to address the problems experienced; the confused definition and scattered attribution of roles and power to different ministries and strata of government; and a context of political interventionism and laxity in law enforcement.

Most of the Thai legal provisions regarding water issues are widely regarded as outmoded (Wongbandit 1995). A Water Law has been considered, together with the creation of a 'Water Ministry', but ill-fated drafts have been stalled in bureaucratic processes for almost 10 years and have not drawn consensus or enthusiasm from analysts[19] (Christensen and Boon-Long 1994) or the community. There is a notorious fragmentation of responsibilities and roles regarding water resources among the different segments of the Thai administration (a circumstance shared by many countries). There is a list of 30 departments concerned with water issues that belong to seven different ministries (Arbhabhirama et al. 1988). Decision-making regarding water-use projects, for example, shows that the right hand can ignore what the left hand is doing. While water resource supplies in many basins are already much lower than demand, it can be observed that several departments nevertheless continue to develop new irrigation areas (Anukularmphai 2000). The Department of Energy Development and Promotion (DEDP) is promoting investment in pumping stations for groups of farmers along main rivers which are already over-exploited. RID's offices at the provincial level also engage in the expansion of the irrigated area at the edges of the delta, diverting water from the very irrigation canals that already provide insufficient supply to the delta proper.[20]

Political intervention in the ministries, in particular that of Agriculture, is also a factor that works against the application of measures of common interest. A high ranking officer of the Ministry of Agriculture summarised the situation admitting that 'the agencies were unable to coordinate their policies because they were supervised by different parties in the ruling coalition' (The Nation, June 2000; emphasis added). Political and technical points of view are often at loggerheads, most often at the expense of the latter. This was illustrated by the 1999 dry-season when, on the one hand, RID officers militated for a 'zero area target', because of extremely low available stocks in the dams, while on the other, politicians claimed and successfully obtained water releases for 300,000 ha of rice. What is at stake, in such instances, is the level of risk (both for water supply and in political terms) incurred, in the absence of negotiated standards.

Legal provisions are obviously useless without a basic capacity for law enforcement and penalties, an aspect in which Thailand admittedly has an unimpressive record (Christensen and Boon-Long 1994; Kraisoraphong 1995;[21] Wongbandit 1995; Flaherty et al. 1999). The question of groundwater in BMA provides the most glaring example of mismanagement with dramatic consequences. In the late 1990s, the failure to control water abstraction and land subsidence reached alarming proportions, resulting in horrendous costs in flood damage and in upgrading flood protection. In 2000, the city still sinks by an average 2 cm/year (Industrial water use to be targeted, The Nation, 25 June 2000). The Acts Controlling the Rent of Paddy Land of 1950 and 1974 are other well known examples of pieces of legislation turned into dead letters (Molle and Srijantr 1999). Bans on sand dredging in riverbeds, on logging, on

19. However, it must be noted that this situation is not peculiar to Thailand. Countries like Sri Lanka or some States of India have been debating water laws for 30 years without effectively enacting a law (Shah et al. 2001).

20. International agencies are also not exempt from such contradictions, as shown by the World Bank's funding of the Pitsanulok Project or examples from Algeria, where the Bank supported both irrigation *Projects* and urban water supply networks in competition for the same scarce resource (Winpenny 1994).

21. 'Thai society has not been known to be a legally conformative one…[and] is built on personal relationships, not on principle or laws.'

inland tiger prawn farming, or the prohibition on use of irrigation water on golf courses, have also been widely ignored.

The only consensus on the way forward in water reform at present is that of the necessity for river basin organisations, but this has so far failed to translate into any concrete measures and legislation. The government and international agencies are supporting several pilot initiatives of water basin organisations (WBO), but it remains unclear if and how they will be able to operate satisfactorily in the absence of strong political backing and legal empowerment. Even if quality service in water distribution can be ensured, it cannot be inferred that the participation of farmers will be smoothly incorporated into the decision-making process. What is known about the resilience of the Thai 'bureaucratic polity' (see, for example, Nelson (1998) and Arghiros (1999)) should preclude any optimism on the extent of the decentralisation process, as well as on the propensity of the administration to hand over its power swiftly and willingly. Therefore, the odds are high that these pilot WBOs will remain formal institutions with no real power and little degree of people empowerment.[22] A positive way of looking at the ongoing processes is to view these initiatives as part of a learning process. However, there is a risk that a partial failure would also make the participation of farmers increasingly difficult in the future.

Conclusions

The first part of this paper was devoted to the examination of a few axiomatic statements that are generally accepted as basic tenets of a conventional wisdom on water management in Thailand, most particularly in the Chao Phraya River Basin. The confrontation of these theoretical (sometimes journalistic) assertions with real world observations shows that the mere copycat replication of general principles elaborated in different contexts is misleading, and that a bandwagon syndrome can develop by sticking to blueprints based on such rationales.

Most arguments put forward to support the introduction of water charges or water markets were proven to be weak, flawed or unconvincing. Water-use efficiency at the basin level is actually (very) high, in contrast to the perception of it being low, and reflects how water management and access to water resources have been changing in the last two decades, as the basin has gradually closed. The contradiction reveals the common lack of understanding on the issue of embedded water balances at different levels of a river basin. It has also been shown that the centralised water allocation system has handled the issue of allocating water to activities with higher economic return relatively well, and that the assumed 'lion's share' of water for agriculture is actually the (fluctuating) left-over water in the system (after allocation to higher priority uses are met). With reduced scope for achieving water savings or economic re-allocation, the concepts of a water charge or water markets lose most of their appeal. In addition, their application would be critically constrained by several practical aspects: the high heterogeneity in the access to water, and in the social cohesion of farmers; the lack of control over water at the basin level, of metering and conveyance facilities; and the presence of numerous, hard-to-identify, small-scale users. Cost recovery also appeared as a questionable objective, when seen in the wider national context of taxation and subsidisation.

However, the 'virtuous' linkage existing between structural, managerial, institutional and financial approaches was recognised (Small 1996), with the pricing of water considered as a mere reinforcing factor of a contractual binding between RID and groups of users. Such a reform—considering the wholesaling of water to groups—was outlined but emphasis was placed on the existing gap between its prerequisites and the current situation. It was recognised that defining a 'service', water rights or water markets, demands a background of legal consistency, administrative accountability and law enforcement that is rarely found in developing countries (Sampath 1992), where, on the contrary, 'capability in both management and regulation is limited and the social and environmental risks of getting it wrong are considerable' (Morris 1996). The definition of water rights potentially leading to re-allocation would be associated with much political stress and, as Allan (1999) has put it, 'regional politicians have a powerful

[22] The examination of the eight existing WBOs showed that farmers are grossly under-represented. The WBOs of the upper and lower Ping rivers, for example, have only two farmer representatives, compared with 22 and 20 officials respectively… To some extent, WBO might suffer from the same lack of political/institutional support and formalisation which affects, 'upstream' of them, the Office of the National Water Resources Committee (ONWRC) and, 'downstream', the WUGs.

intuition that economic principles and the allocative measures which follow logically from them must be avoided at all costs…Government are more likely to rely on the exhaustion of the resource to be the evidence that persuades water using communities that patterns of water use have to change'. Defining a water 'service' involves not only technological issues (improved facilities and modernisation of hydraulic regulation), but also the empowerment of administrative bodies with sufficient power to coordinate the agencies concerned, to register uses and users, to enforce basin-wide control and apply penalties, and to set a process in which representatives from the various lower levels of the basin may participate in devising sound and negotiated allocation plans and guidelines to meet demand of equity in the context of year-to-year fluctuating water stocks. Such a body/ bodies must also be provided with sufficient autonomy to avoid that intervention of politicians overriding technical decisions.

At the level of the water user groups, similar mechanisms must be established. The allocation of water within the group (in particular when water is short of demand), procedures for its distribution, definition of water fees and their collection, and the devising of rules and penalties and their enforcement, are essential yet are contingent on the effective negotiation of, and assured delivery of, the 'water service'. Thus, the timing of the different actions and the occurrence their supposed effects are of paramount importance. It must be remembered that the establishment of WUGs is doomed to face the same fate of earlier attempts if it is not concomitant (rather than followed) with clear and perceived new benefits for farmers, in terms of amount, reliability and timing of water supply.

Considering the daunting list of prerequisites to the establishment of 'water wholesaling' and water rights (let alone markets), it is obvious that the opportunities to expand such mechanisms are more limited than suggested in the literature. The example of Thailand is probably representative of a much larger context, including the bulk of Asian medium–large scale irrigation. Thailand shows that situations with no possible volumetric metering, a very high number of small farms with differentiated and fluctuating levels of access to water, committed to wet rice cultivation with severe environmental and market constraints to diversification, weak legal and institutional environments, and significant political meddling, are unlikely to be in a position to benefit from such mechanisms, at least in the foreseeable future.

The critical impositions made to the institutional and political settings should preclude over-enthusiasm and, rather, prudence, gradual reform, testing in pilot areas and in-depth awareness-building, training, negotiation and discussions with all stakeholders, including politicians, are needed. Concomitantly, this process should be geared towards effective river basin organisations giving a say to all users and being provided with sufficient power, legal and political backing, and clear mandates to control, allocate and manage water resources. A worrying aspect of the water pricing reforms presently envisaged is that they stem from ideologically driven external pressure rather than from an endogenous awareness of the seriousness of the situation of the water sector. Experience from other countries suggests that limited success can be expected in contexts where both the administration and politicians are reluctant or passive. Although some signals for change are already visible (Prechawit 2000), it is doubtful that the degree of awareness of stakeholders and of their understanding of the complexity of the issue are, at the present time, compatible with a wide scale and far reaching reform. It is also debatable whether the potential benefits in efficiency, equity and security are equal to the difficulties and costs of implementing it.

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The Economics of Water Allocation in Thailand

Piyanuch Wuttisorn*

Abstract

There is general consensus that water shortages have become more common. This paper provide an overview of how economic analyses contribute to understanding the problems of water allocation including institutional and regulatory arrangements in Thailand's water economy. Clarification of misconceptions and economic terms is provided. Some examples of the economic applications to water allocation problems are presented to provide into insight into the use of economics in tackling water allocation problems.

> Economic analysis has much to offer those who seek to understand water issues and evaluate alternative policy strategies. (Randall 1981, p. 197)

THIS paper explores ways in which economics can contribute to water resources problems. Some of the questions and criticisms involving the application of economic analysis to water resources problems in Thailand are addressed.

There is general consensus that water shortages have become more common. In addition, the resource is usually in the wrong place or available at the wrong time relative to demand. As water is a scarce and valuable resource, there are different views of stakeholders in society as to how water should be allocated. Conflicts of interest are not uncommon for natural resources. Gladwin (as quoted in Izac (1986)) conducts an analysis of 3,000 natural resource cases in 40 countries and points out that, in each of these cases, the interests of various groups of users of the resource have conflicted. Economists have maintained a prolonged interest in water-related issues. Water scarcity stimulates the application of the economics discipline to water resource allocation. Flinn and Guise (1970) argued, in the context of an application of spatial equilibrium analysis to water resource allocation in Australia, that economic principles can provide an informative perspective on water allocation problems. They noted (Flinn and Guise 1970, p. 398):

> The involvement of economists in these [water allocations] does not imply that a competitive market for water necessarily provides an adequate solution to problems of water allocation and pricing from a social viewpoint. Conflicts among competing water users will inevitably continue, and politics, rather than economics, will be the final arbiter in the solution of such conflicts. However, the areas of conflict may be narrowed, and better choices may result if clear statements about equilibrium prices and the resulting distribution of water among competing user are available.

The problems surrounding water allocation are complex. They involve, for example, externalities, uncertainty of the resource in seasonal conditions, infrastructure limitations, and social and political concerns. Given such complexity, economists need to be fully aware of the constraints in the analytical frameworks of economics to capture all aspects of reality of the water resource allocation problem. This is because mainstream economics is methodologically oriented toward simplification and abstraction. Likewise, other disciplines should take into account the limitations imposed by their own analytical frameworks. Water issues are interdisciplinary; thus a combination of established disciplines would eventually bring about better solutions for water problems in Thailand and elsewhere.

In attempting to understand the complexity of water problems in Thailand, clarification of the economic concepts and analytical framework for water problems is needed for better insights of how economists could play a role in water allocation. At a very general level of discussion, water-related problems consist of two components, namely water allocation

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and institutional arrangements. These two components determine how water resources must be allocated and managed; and what types of institutional arrangements need to be established in order to optimise economic welfare and achieve efficient resource allocation and social efficiency.

This paper provides an overview of how economic analyses contribute to understanding the problems of water allocation including institutional and regulatory arrangements in Thailand's water economy. Moreover, a clarification of misconceptions and economic terms is provided. Some examples of the economic applications to water allocation problems are presented to provide an insight into the use of economics in tackling water allocation problems.

Characteristics of the Water Economy

Randall (1981) classified the water economy into two phases, namely expansionary and mature phases. The expansionary phase is identified by elastic supply of 'new' water supply and the low but growing demand for the water delivered. The mature phase is identified by inelastic supply of 'new' water and the need for expensive rehabilitation of aging projects. Different phases of the water economy require different applications of water policies. An analytical framework derived from the work of Randall (1981) is adopted for the identification of the water economy in Thailand. The characteristics of the two phases of the water economy, namely expansionary and mature phases, are provided Table 1.

Table 1. The characteristics of expansionary and mature phases of the water economy.

Item	Expansionary phase	Mature phase
1. Long-run supply of impounded water	Elastic, i.e. not very expensive to augment supplies, many low-cost opportunities for water resource development	Inelastic, i.e. limited opportunities available for augmenting new supplies, and very expensive
2. Demand for delivered water	Low, but growing; elastic at low prices, inelastic at high prices, i.e. at low prices there are many users who demand a great deal extra when the price varies a bit; at high prices users are unresponsive to price changes (these are high-valued essential uses)	High and growing; elastic at low prices, inelastic at high prices
3. Physical condition of impoundment and delivery systems	Most are fairly new and in good condition	A substantial proportion is aging and in need of expensive repair and renovation
4. Competition for water among agricultural, industrial and urban uses, and in-stream flow maintenance	Minimal	Intense
5. Externality etc., problems, i.e. externality occurs in the situation of a utility of a party is affected not only by own activities but by activities controlled by others	Minimal	Pressing: rising watertables, land salinisation, saline return flows, groundwater salinisation, water pollution etc.
6. Social cost of subsidising increased water use	Fairly low	High and rising

Source: adapted from Randall (1981, p. 196).

According to Randall (1981), Australia's water economy is a prime example of a mature water economy. His study shows the estimated demand for Murray–Darling irrigation water, and the (hypothetical) marginal cost of irrigation water as illustrated in Figure 1.

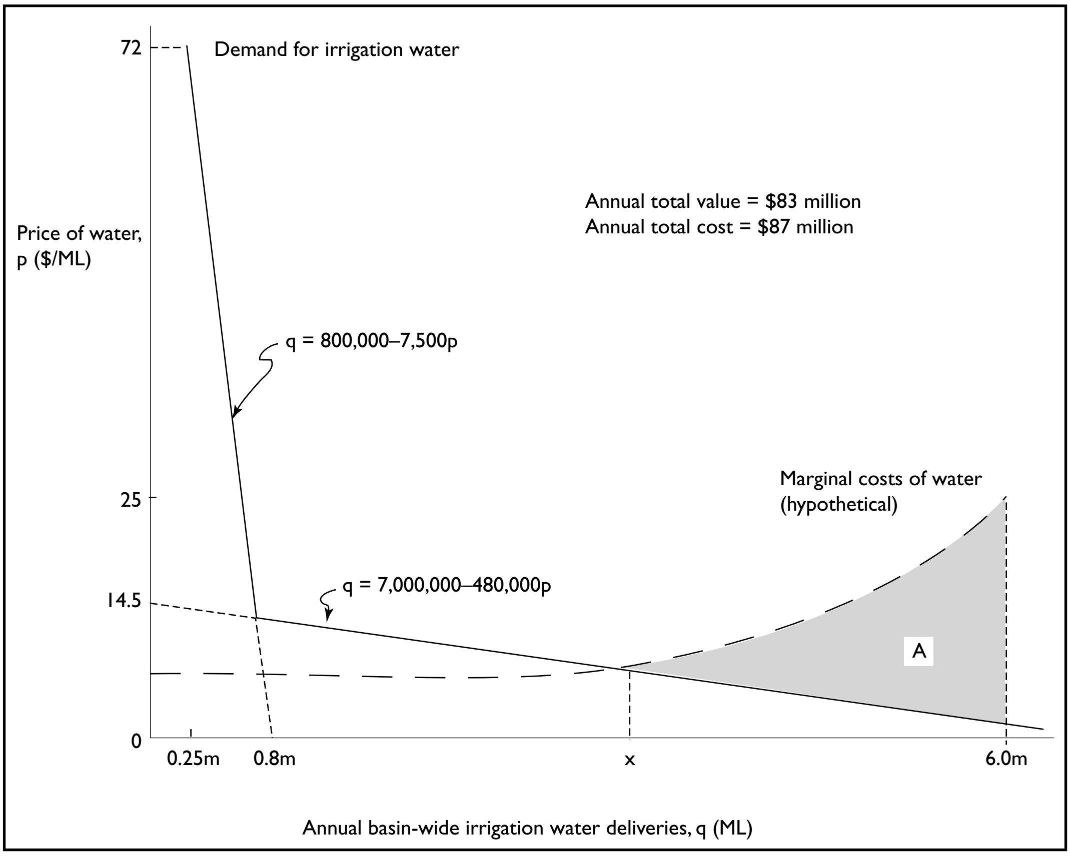

Figure 1. Estimated demand for Murray–Darling irrigation water and (hypothetical) marginal cost.
Source: derived from Randall (1981).

At the policy/decision-making level, it is important to identify whether or not the water economy is entering a mature phase. It is apparent that Thailand's water economy is entering a mature phase. Development of new water supply is difficult due to physical, financial, and environmental limitations. In the past, the development of new water supplies was the main approach to provide water to meet demands from all water users. However, under the current situation it is well recognised that rapidly growing demand for water cannot be easily met through new investments in water supplies. Although urbanisation continues to increase in the lower Chao Phraya basin, Thailand can effectively demand more water via inter-basin transfer, i.e. from the Mae Klong basin. New water development is increasingly difficult, not only in terms of budget constraints, but also because of the opposition of people in the Mae Klong basin. This increasing difficulty and high cost has changed the focus on expanding water supplies to considering other alternatives in water management; that is, the demand management approach. Governments are now still (and will continue to be) an inevitable part of future water allocation decisions, at least in setting the 'rules of the game'. There are several reasons why governments play a role in the water sectors, e.g. lack of well-defined property rights, characteristics of water as a public good, natural monopoly etc.

Arguments about the Application of the Concepts of the Economic Scarcity of Water

There is strong opposition from non-government organisations (NGOs), and non-economists to the application of the concepts of economic scarcity of water, i.e. market-based solutions for water. This opposition stems partly from major misconceptions about economic terms. It appears that common knowledge for the resolutions of water problems includes two polarised views of resolutions, namely markets and government controls. Of these two views, market-based solutions are recognised (by those who have shown their strong opposition towards markets) to be less popular and less advantageous. However, reliable research evidence to support this argument is still required. It seems that these two conflicting views relating to water solutions are difficult to reconcile due to the extremely different rationales underpinning the two thoughts. The solutions for water problems are not yet conclusive. Under this circumstance, there is an urgent need to take a more careful look at factors determining social desirability and political feasibility of market-based alternatives.

There is growing pressure for water reforms all around the world including Thailand. Market efficiency and economic welfare are among diverse objectives of water allocation. However, the physical characteristics of water add a considerable degree of complexity to allocation and commonly reach controversy when market-based solutions are proposed for water allocation with particular reference to water for agriculture. That aptly describes the current situation in Thailand's water economy. In Thailand, it is apparent that no water charges for agriculture and low water charges for water supply utility are one of the ways the Thai government subsidises the two sectors. This subsidisation is common in developing countries.

The following section is organised to discuss four major misconceptions about economic terms. These misconceptions include: technical versus economic efficiency; methods for achieving economic efficiency; the concept of marginal value and income distribution issues; and open access versus common pool resources.

Technical versus economic efficiency

There is a misconception about the terms relating to 'efficiency'. The two terms— 'technical (physical) efficiency' and 'economic efficiency'—appear to be misunderstood and used interchangeably in error. These terms are very different and these differences must be clarified.

Physical efficiency

The principle of technical (physical) efficiency is based on the efficiency of water use in terms of water conservation, and compares water beneficially used with water actually applied. Two indicators used to measure the technical efficiency are 'classical irrigation efficiency' and 'modified classical irrigation efficiency'. Burt et al. (1997, as quoted in Rosegrant 2001, p. 3) classify physical efficiency in terms of 'classical irrigation efficiency', IE_c, described as follows:

Keller and Keller (1995), and Keller et al. (2000) (as quoted in Rosegrant (2001, p. 4)) modify this equation by taking into account the potential re-uses of irrigation return flows as shown below.

Physical efficiency can be enhanced by different irrigation technologies. In Thailand, the traditional and most common form of irrigation technology delivers water by gravity. Given such irrigation technology, the physical efficiency can be enhanced to only a certain level and can be further improved only by the application of advanced irrigation technologies such as sprinkler and drip irrigation. It is worth noting that that, even where water use is technically inefficient, there is much debate about how much conservation will be achieved by improved technology. This is because the water that is 'wasted' tends to flow back into the system (return flows) for use downstream (Rosegrant 2001).

Economic efficiency

The principle of economic efficiency is based on the value of water. The value of water may be defined in terms of resource cost, opportunity cost, and social cost. The resource cost is the cost of providing water itself, i.e. the cost of the engineering works required to capture and deliver the water to the users. The opportunity cost is the value of that water in its best alternative use. The terms 'economic cost' and 'opportunity cost' are often used interchangeably. What they mean is that in one application of water the opportunity of using water elsewhere is foregone. One way of understanding the concept of opportunity cost is to consider the gross profits per unit of water as shown in Table 2 and interpret their meanings. The gross profit per unit of water used in fruit production indicates that 1 ML applied for the production of fruit produces the highest return, and is therefore the best alternative use under this particular circumstance. In the case of dairy products, the opportunity costs of foregone uses are those of the gross profit of water from the productions of fruit or vegetables, which yielded A$500 and A$217, respectively, per a megalitre of water. As suggested by Quiggin (2001), another way of interpreting Table 2 is to consider the implication of changes in water prices for profitability, which is in turn indicated by the value of water (Quiggin 2001, p. 69):

> If the price of water increased by A$40 per megalitre, the use of irrigation for pasture would become unprofitable, and the gross margin from irrigated rice production would fall by nearly 75%. By contrast, the profitability of fruit and vegetable production would barely be affected.

Table 2. Water required for selected commodities, for A$1,000 gross profit.

Commodity	Water use (ML)	Gross profit per unit of water[a] (A$/ML)
Fruit	2.0	500
Vegetables	4.6	217
Dairy products	5.0	200
Cotton	7.6	132
Rice	18.5	54
Pasture	27.8	40

[a] Gross profit per unit of water is calculated by gross profit of A$ 1,000 divided by the amount of water use, i.e average value of water for fruit: A$ 1,000/2 ML = A$500/ML.
Source: adapted from Hall et al. (1993, as quoted in Quiggin 2001, p. 70).

In a mature water economy, the opportunity cost of water will usually be higher than the cost of delivery services, i.e. the resource cost. This is because the cost of augmenting new supplies, which could otherwise satisfy the extra demand, is higher than the cost of existing works.

The social cost is its true cost to society, and internalises positive and negative externalities. Negative externalities include, for example, rising watertables, land salinisation, salt-water intrusion, groundwater salinisation, water quality problems, loss of biodiversity etc. In economic terms, an externality occurs in the context of a utility if a party is affected not only by their own activities but also by activities controlled by others. An individual utility function in a simple economy with two consumers (*A* and *B*) and two commodities (*X*, *Y*) can be described by: $UA = U(X_A, Y_A, X_B)$. While the potential for external costs and benefits of water use is recognised, they are not treated in the subsequent discussion, in which the objective is to highlight the concept of opportunity cost.

In the context of economic efficiency, the value of water is determined by equating the price of water with the marginal value of use with the marginal opportunity cost of use forgone. This efficiency is based on the concept of 'opportunity cost'. In other words, water should be allocated to high-value activities that yield a very high return per unit of water applied. At a basin level, the economically efficient allocation of water is determined by the amount of water which, if allocated to each user in the basin, would result in the highest return for the amount of water available. This leads to the concepts of the value of marginal product, which will be discussed in a later section.

The value of marginal product is the individual-demand curve of water (see Figure 2). When the individual-demand curve is defined, the regional-demand for water can be derived. In a simple economy with two water users, the regional-demand for water (i.e. the industry water demand) is defined as shown in Figure 3.

The value of marginal product can be written as:

$$VMP_w = P_{xi} MP_x^w$$

where $VMPw$ = value of marginal product;

P_{xi}= price of commodity *xi*; and

$MP^w{}_x$ = marginal product of one more unit of water applied to commodity *x*.

Investigation of the marginal product value of irrigation water in Thailand shows that it varies across irrigation projects and systems (i.e. pumping irrigation and gravity irrigation) and water supply sources (i.e. surface water and groundwater). The marginal product value (nominal value) of irrigation water in the Mae Taeng irrigation project, which is located in the north-

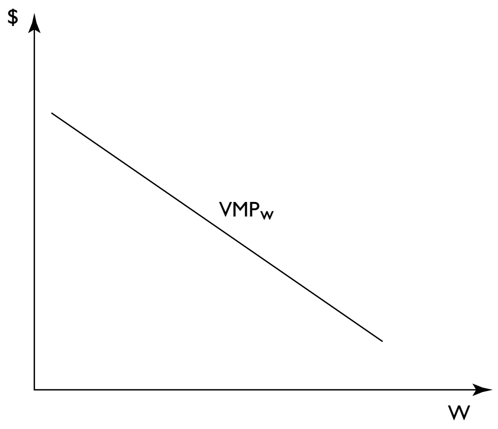

Figure 2. Value of marginal product for water.

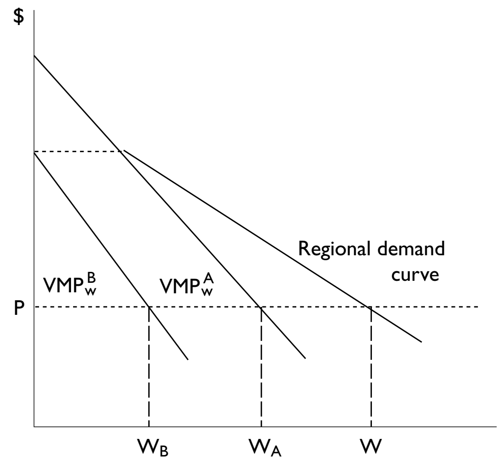

Figure 3. A regional demand curve for water.

ern part of Thailand, was approximately 1 baht/m^3 during the period of 1980 to 1991 (see Table 3).

Table 3. Marginal value of water in Mae Taeng, Thailand.

Year	Marginal value of irrigated water (baht/m^3)
1980	1.06
1981	0.97
1982	1.04
1983	0.91
1984	1.04
1985	1.02
1986	1.02
1987	1.12
1988	1.55
1989	1.66
1990	1.52
1991	1.58

Note: Marginal revenue values are current (nominal) baht/m^3. Source: Thailand Development Research Institute (as quoted in Vincent et al. (1995)).

Kaosa-ard (2001) estimate the marginal value product of irrigated water in selected irrigation projects (see Table 4). Interestingly, the marginal value product of irrigation water in the Greater Chao Phraya irrigation scheme (gravity only irrigation system) is 0.18 baht/m^3, the lowest value among the selected irrigation areas.

The difference of marginal value product of irrigation water might stem from different factors, for example, the different prices of the different commodities for which water is used, the available technology (e.g. infrastructure constraints, irrigation system), and physical conditions in specific locations (e.g. soil, climate etc.).

This study points out that the existing water allocation system, which normally focuses on releasing water from upper levels of the Chao Phraya basin to be used in the lower Chao Phraya irrigation area, and diverting water from the nearby Mae Klong river basin, should be reconsidered. This is because of the relatively low benefit of using water in the lower basin. The relatively low marginal value product in the lower Chao Phraya area to an extent contradicts the common view of the lower Chao Phraya area, which is recognised as the rice bowl of the country, creating a great deal of economic value to the country.

There are many interconnected issues involved in the discussion of the context of efficiency in this section, but in summary, the concept of economic efficiency is considered to be broader than that of physical efficiency. That is, the economic efficiency may be enhanced under any existing irrigation technologies.

Table 4. Marginal value product of irrigated water in selected irrigation projects.

Irrigation project	Marginal value product of irrigated water (baht/m^3)
The Chao Phraya Basin	
1. Pitsanulok irrigation project	2.42
2. Pumping irrigation project, lower north region (operated by the Department of Energy Development and Promotion)	5.30
3. Pumping irrigation project, Tak province (operated by Royal Irrigation Department, RID)	1.48
4. Groundwater irrigation project, Sukhothai province	4.35
5. Greater Chao Phraya irrigation projects (gravity system)	0.18
6. Pumping irrigation project, Greater Chao Phraya irrigation scheme (operated by RID)	1.65
The Mae Klong River Basin	
1. Mae Klong irrigation project	1.60

Source: adapted from Kaosa-ard (2001).

Methods for achieving economic efficiency

There are several methods for achieving economic efficiency. It appears that market-based solutions are the major approaches adopted to tackle water problems in developed countries, e.g. the United State of America and Australia, where water conditions and agricultural practices are completely different from those of Thailand. In Thailand, it is believed that markets or market-based solutions are not appropriate for water. The argument mainly stems from the notion that water is for everyone. This major notion induces people to believe that free access to water is a fundamental right of human beings. It should be made clear that the concepts of economic scarcity of water do not imply that volumetric fees that cover the opportunity cost of water are the only solution economists have to offer. Methods for achieving economic efficiency include, for example, improved institutional arrangements and entitlement systems that allow effective rationing of water, through informal transfers or through formal water markets.

In Australia, the idea of introducing volumetric charging at the opportunity cost of water for achieving economic efficiency would never have been acceptable. This is because people have traditionally had a right to the water and because they probably paid for the value of the water when they bought their land. The value of water and land are heavily tied together, i.e. in an irrigation area people would have paid much more for their land relative to land in nearby dryland areas. Introduction of full volumetric charging would be like double charging. Therefore, the method that they used to introduce information about opportunity cost was to have a water market. Farmers were given formal volumetric rights to the water that they had traditionally had access too, and were allowed to trade them. Farmers were also charged a volumetric fee to cover the cost of the irrigation delivery infrastructure. Those farmers who used water on low-value crops found that they were better off selling their water to people who valued it more. It also ensured that they were 'compensated' for giving up their water. Water trading in Australia has proven that the water market can be operated in the real world. The top nine private water owners are in the cotton trade, and water is used on their properties. The price of a megalitre of water is reported to have doubled from $400 to $800 over the last four years. Still, the market operation is under the process of reform, to better protect the Murray River, and to make the market more efficient. The environment and the riverine system are the issues of concern.

However, introducing water markets might not be appropriate for Thailand because the cost of administering water trading would be too high for smallholders (e.g. metering costs). The principle used is that farmers are not 'taxed' for something that they have had traditional rights to, but at the same time they are made aware of the opportunity cost of water. It has improved the efficiency of water use (adoption of water saving technology) and allowed water to be used, within the irrigation sector, on more valuable crops, for example, the interstate water trade in Australia which is shifting New South Wales and Victorian water down the Murray to grape growers in South Australia.

The concept of value of marginal product: income distribution issues

In general, reallocating water to activities that are of higher value is of great concern of society, as there is a common perception that water uses in agriculture are less valuable in those in other sectors. Farmers need to be protected against losing their property rights in using water because they have low bargaining powers compared with those in non-agricultural sectors. It is important to note that economists do not necessarily propose water pricing (that is, taxing at full opportunity cost) as the best approach to water policy reform. Rather, drawing attention to the need to define non-attenuated water property rights is a significant pre-condition for taking further steps in reallocating water based on economic instruments. If rights are recognised, then a mechanism is put in place to ensure compensation of existing users.

According to Demsetz's view, property rights are defined as specifying 'how persons may be benefited or harmed, and therefore who must pay whom to modify the actions taken by persons' (Demsetz 1967, p. 347). Non-attenuated property rights ensure Pareto-efficiency. A set of nonattenuated property rights includes four characteristics (Randall 1987).

- Completely specified, so as to provide perfect information about the rights that accompany ownership, the restrictions on those rights, and the penalties on their violation.
- Exclusive, so that all rewards and penalties resulting from an action accrue to the agent holding the rights. Thus, all profits and costs can be internalised and private and social marginal costs can, in principle, be equated.
- Transferable, the transferability allows rights moving to highest values, thus marginal conditions for allocation can be applied.
- Enforceable and completely enforced, this is essential for reducing uncertainty. As Randall indicates, an unenforced right is no right at all.

However, Randall argues that the definition of non-attenuated property rights is ideal, and is correct only if transaction activities are costless. Izac (1986) refers to the Chicagoan or property rights paradigm, proposed by Coase in 1960, that a resource remains unpriced if the costs of establishing property rights over that resource are higher than the benefits of the action. The resource becomes a market good; that is, property rights are created over the resource if the benefits of property right creation are higher than the costs.

In Thailand, farmers rely heavily on withdrawals from surface water sources and provision of regulated surface water from the Royal Irrigation Department. It is suggested that the allocation of this water is based generally on water rights doctrines rather than on water markets. Two key principles, a priority list or queue of water users and a bureaucratic mechanism for ascertaining the quantities of water to be withdrawn by individual users, underpin such water rights doctrines. However, this allocative system is likely to be less efficient than markets in allocating scarce resources. An open research question is whether efficient water management matters. This has already been addressed in the context of, for example, the Maipo River Basin in Chile. To date, this urgent and challenging question has not been explored in the context of Thailand's water. The real gains of efficient allocation, and the best method of achieving reallocation, depend on the magnitude of the scarcity (and the degree to which the opportunity cost differs between users). It is essential that the economic analytical frameworks deployed to water problems should be able to address these issues.

Open access versus common pool resource

There are misconceptions about the water property rights regimes 'open access' and 'common pool resource', and the two terms are used interchangeably. Challen (2000) indicates that the problems relating to the terminology used to define property rights have persisted. The seminal literature on the joint use of natural resources by multiple parties (Gordon 1954; Demsetz 1967; Hardin 1968; Quiggin 1988 (as quoted in Challen (2000, p. 22); Bromley and Cernea 1989; Bromley 1991) shows that failure to properly distinguish the property-right regimes has led to errors in description and economic assessment of actual and historical common-property situations.

Bromley (1989, as quoted in Challen 2000, p. 21) describes open access (or non-property) and common property by referring to:

> Open access: the property right regime, which there is no defined groups of users or owners exists and the benefit stream from use of the resource is available for everyone; common property right is identified as a management group of owners has a right to exclude non-members, and non-members have a duty to abide by exclusion.

But there are rules governing the uses of water in Thailand, and the term 'open access' therefore does not properly represent the property rights regime for water there. Rules governing the uses of water do exist in many forms; for example, laws, regulations, common practices etc.

Moreover, it is clear that different property rights regimes require different analytical frameworks. In the context of Thailand's water economy, the tendency will be towards undertaking water reforms through the establishment of institutions based on the concepts of efficiency, by assigning the water property rights of common pool resources. These institutional arrangements are needed to ensure that all water users get equal access to water. This prospective new water regime would eventually replace an existing water regime in the country—state property. The characteristics of property-right regimes based on the classification scheme are shown in Table 5.

Issues of Institutional Reform

Current reform process in Thailand

Thailand is now in the process of undertaking water reforms. Recently, there has been considerable effort by government and international agencies towards the process of water reforms in order to reallocate water on the basis of equity and efficiency. Pressures for institutional changes in water regimes largely stemmed from external sources, e.g. The World Bank and Asian Development Bank, with collaboration from Thai government agencies. A study of basin-wide water resources development started in 1993, covering 25 river basins. This was a significant milestone in attempts towards water resources management through systematic analysis.

The idea of the profitability of water by the application of water pricing and other market-based solutions first appeared in the Seventh National Economic and Social Development Plan, operating since 1992. It has been accepted at the policy level that the allocation of water needs alternative and innovative mechanisms to manage water more efficiently. However, it is not yet clear how market-based solutions would be applied to water in Thailand. Under existing Thai culture, water users, especially farmers, believe that they have the right to freely access water. Water pricing is one of the most politically sensitive issues in Thailand. The application of water pricing is generally believed to be difficult. Farmers are regarded as the poor in the country, and they are unable to bear any additional costs. This issue is clearly related to politics. Politicians are reluctant to support water-pricing reforms mainly because people in the agricultural sector are a major voting bloc, and their suffering might lead to loss of their political support.

Table 5. The characteristics of property-right regimes.

	Property-right regimes			
	State property	**Common property**	**Private property**	**Open access**
User limitations	As determined by state agency	Finite and exclusive group	One person	Open to anyone
Use limitations	Rules determined by a state agency	Rules determined by mutual agreement	Individual decision	Unlimited

Source: Challen (2000).

Recently, the Asian Development Bank has imposed a condition for the loan to Thailand that water pricing should be applied to agricultural uses. This loan condition has created immense conflicts of thoughts in the country, and has drawn great attention to the controversial debate on water pricing. A comprehensive study recently completed by Molle (2001) clearly points out that, although some signals for changes towards water pricing are already visible, it is untimely and improper in the Thai water context, as the pressure for change stems from external sources. In addition, preconditions of water pricing reforms are needed, for example, in-depth awareness building (of the complexity of the pricing-related issues), training, negotiation, and discussions with all stakeholders, including politicians. Molle (2001, p.70) notes that the process of water pricing reforms:

> ... should be geared towards effective River Basin Organisations giving a say to all users and provided with sufficient power, legal and political backing, and clear mandates to control, allocate and manage water resources.

It is reported that no country has been able to successfully implement opportunity cost pricing of water administratively due to serious practical and political problems. However, in principle it is essential to consider the concept of opportunity cost when water allocation decisions are being made. It is worth noting that whenever water pricing is discussed the focus is on the pricing based on the resource cost, rather than that of full opportunity cost. The pricing based on the resource cost, or cost recovery pricing, would make it difficult to implement in Thailand where the investments in water supplies have traditionally been the government's responsibility. However, since the provision of water supplies is set up there is a need to consider the water allocation in the most efficient way based on the concept of opportunity cost rather than the concept of recouping revenue to pay back the water supply investments. This is because water is not as plentiful as it was in the past.

Water law reforms are proceeding in the Office of the Council of State, the law-drafting agency of the Thai Government. It is believed that the provision of the new Water Law will facilitate the development process of water reforms, especially water institutional and regulatory bodies promoting efficiency and equity. However, several studies have pointed out that the new water law would not bring about much efficiency and equity. Likewise, at administrative levels, there is an attempt to set up a new management arrangement based on a basin-wide management approach. By this approach, it is planned that the major river basins in Thailand will be administered by their own basin committees. Each committee comprises representatives from the Royal Irrigation Department, agencies at provincial level, and private stakeholders at local level. But these river basin committees do not yet have a legal foundation. To streamline water management developments within the government sector, there are some significant resolutions before the Cabinet. They are the establishment of (1) the legal foundation for the National Water Resources Committee (NWRC) and the Office of the National Water Resources Committee (ONWRC), (2) River Basin Committees, and (3) Water User Organisations. Judging from the degree of water reforms being proposed in the Thailand, it appears that it is now recognised that the current system of water resources management is inefficient. There is a general perception that the existing institutional and regulatory arrangements for water resources need to be altered. More specifically, there is more support for the idea that water might not be being allocated efficiently and the allocation does not reflect the economic value of water.

Evaluation issues

There is an overwhelming lack of economic analysis to support the debate on different water policies in the context of Thailand. Consultants have proposed a number of proposals for institutional changes in water. But an evaluation of what is 'economically good' or 'economically bad' has not been undertaken. In particular, determining the consequences and impacts of different water policies at a macro level has not yet been thoroughly undertaken. This shortfall shows a large need for economic analysis, i.e. a determination of the best way of analysing institutional problems and proposed institutional structures of water reforms in Thailand. The key point is how much we might potentially gain from better allocation of water resources should be able to quantify outcomes.

An Analytical Framework for the Economics of Water Problems in Thailand

This section outlines an example of an analytical framework of an ongoing research project on the economics of water allocation in Thailand.

Research objectives

The overall objective of the research is to develop an economic model for water allocation, so as to enable the assessment of the economic value of water, the amount allocated, and the amounts traded between sectors and regions. A subsidiary objective is to investigate the current method for water allocation by focusing on the issues of water for agriculture, as the sector shares a prominent use among other users. The specific aims the study are:

- To describe the current method for allocating water in Thailand.
- To analyse the efficiency of the current system and institutional, cultural and government policy constraints associated with water management in Thailand, and their impacts.
- To determine the best way of analysing institutional problems in the water regime in Thailand.
- To analyse optimal water allocation and pricing by using a partial equilibrium framework, spatial equilibrium model.
- To provide recommendations for efficient water allocation based on economic efficiency and welfare equity.

Research methods

Research approaches are initially set to answer the research questions by adopting the two main streams of research analysis described below, namely documentary research, and a mathematical model.

- Review of current institutional, policy, and implementation problems concerning water resource management in Thailand. The key question includes how water is allocated and how water allocation decision-making occurs. In addition, the analysis of the efficiency of the current system will be examined based on the theoretical framework of institutional economics. The main questions to be examined include why water allocation is like it is; whether or not it is changing over time; and if so (or not) why. The analysis aims to bring about not just a description of water institutions in Thailand but also an evaluation of them by examining them in an analytical framework. The outcome of an evaluative overview of institutions would result in a determination of the best way of analysing institutional problems of the water regime in Thailand, rather than proposing the most appropriate institutions for water.
- Construct a set of data for estimating water demands and water supplies. Models of water demand and water supply will be developed to finally obtain regional water demands and supplies at the Chao Phraya Delta level. Demands for water will be characterised according to various types of end uses. There may be five water demands to be estimated in the study. They are water used in agriculture, residential water (i.e. urban and domestic uses), water used for industry and business, water used for hydropower generation, and water required for ecological balance and navigation.
- The derivation of expected water supply is based on modelling technical and hydrological relationships. However, in the short run supply of water would be considered as highly inelastic, thus a fixed supply of water resulting in vertical irrigation water supply in one location. Sources of water supply in the region mostly come from surface water, and a small portion from groundwater. The Delta modelling will be developed by taking into account the supply of regulated surface water flowing into the Delta. Surface water in the Delta is regulated by storage facilities located in the upper Chao Phraya basin, namely the Bhumipol and Sirikit reservoirs.
- Model the efficient allocation and equilibrium prices of water by using a spatial equilibrium model (SEM). Water allocation will be guided by the optimal solutions from the SEM. Conceptually, water will be reallocated from activities which have lower marginal value of use, and make that amount of water available for the activities which have higher marginal value.
- Develop recommendations for water resource management and water development policies.

Conclusion

As noted several times in this paper, it is confirmed that 'economic analysis has much to offer those who seek to understand water issues and evaluate alternative policy strategies' (Randall 1981). One key issue related to the applications of the concepts of the economic scarcity of water is the distinction between the applications of the economic concepts at the levels of principles and practices. Two conditional statements would help describe the difference between the two discussion levels. First, if we were to allocate water more efficiently, how water would be allocated and what the water allocation would look like. Second, if we were to implement the economic methods for achieving efficiency, how the institutions would be designed and put in place. The real gains from efficient allocation, and the best methods for achieving reallocation, depend on the magnitude of the scarcity and degree to which the opportunity cost differs between uses. A wide range of analytical frameworks needs to be used to analyse water problems and to propose policy responses.

In the process of undertaking water reforms, the potential for change is believed to be immense, as all stakeholders in water are aiming to put in place a better water allocation system. However, there are constraints to change in the government hierarchy and in political circles. High commitment from politics is expected to be the most powerful key to success. Radical change is not expected to be the case of water reforms in Thailand. The so-called 'step-by-step' approach would be more appropriate, as the country's water condition has not yet reached an absolutely critical condition. By the time that changes need to be in place, the economic evaluation of different water strategies in Thailand would help the process of decision-making and institutional designs.

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Water Policy, Management and Institutional Arrangement of the Fuyang River Basin in China

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Abstract

Based on a case study of the Fuyang River Basin, one of most serious water-shortage regions in northern China, we find that the conflicts among various stakeholders and an inability to implement water laws and policies have resulted in increasing water shortages and inefficient water use. The basin's water is often separately managed by individual local governments based on administrative jurisdictions. No integrated water management authority exists at the water basin level. Within the administrative jurisdictions, water supply and demand are controlled and managed by too many authorities which have different interests, resulting in various conflicts in balancing water use in the region. Increasingly unbalanced and inefficient water allocation between upstream and downstream users in the river basin has made integrated river basin management very essential. In addition, weakening financial support for water infrastructure investment and low water prices are two other factors that add to the rising gap between water demand and supply in China. The study on property right innovation suggests that the private and shareholding groundwater irrigation system can improve the efficiency of water use. The existing government fiscal and financial policies in irrigation investment need to be revised in order to encourage the development of this market-oriented irrigation management system. The study calls for an urgent need for establishing policy and institutional framework for integrated and effective water resources allocation, planning, and management in the context of comprehensive river basin management. According to main findings of the research, water management action plans at national, regional, river basin and irrigation system levels are proposed.

FACED with a rapidly expanding gap between water supply and demand, and increasing competition among sectors in China, especially in the northern regions, water issues have received increasing attention. In the past, water problems were mainly treated as engineering problems and most water research focused on improving water use efficiency through new water delivery technology (Wu et al. 1986; Chinese Academy of Sciences 1991; Xian Institute of Water Resources 1995). Lack of incentives for the adoption of water-saving technologies at farm-household level reveals the importance of water management and institutional arrangements. Growing evidence also shows that water management and institutional arrangements are important measures for dealing with water shortage problems (World Bank 1993; IWMI and FAO 1995). The conflicts among various stakeholders and an inability to implement water laws and policies result in increasing water shortage and inefficient water use in China (Wang 2000). Although China has issued numerous water policies and regulations since the 1980s, many policies are either too general to implement or lack the institutional support system needed to implement them (Wang and Huang 2000b). Recently, water management agency reforms reflect that China's government has gradually realised the importance of institutional setting and policy in managing the water sector.

While the importance of institution and management has received attention from both decision-makers and scholars recently, few studies can be

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found in the literature that systematically examine these issues at both national/sub-national and river basin levels. Based on a case study on 'Development of Effective Water Management Institutions' in the Fuyang River Basin of China, and a general review of national law, institutions and policies in the water sector, the purpose of this paper is to explore possibilities for institutional reforms that can better foster integrated and sustainable use of water at national, regional and river basin levels.

This paper is organised as follows. In the first section, basic characteristics and water accounting analysis of the basin and irrigation system in the Fuyang River Basin are discussed. Water policy, management and institutional arrangements at national, river basin and irrigation system are the main contents of the next three sections. The fifth section discusses the empirical research on determinants and impacts of property rights innovation for groundwater irrigation systems. Concluding remarks on emerging challenges of water management and corresponding action plans are provided in the last section.

Basic Characteristics and Water Accounting Analysis

Overview of the Fuyang River Basin (FRB)

Location, climate and socioeconomic characteristics of the FRB

Traversing five prefectures (Handan, Shijiazhuang, Xingtai, Hengshui and Cangzhou) of southwest of Hebei province, the Fuyang River is one of two branches of the Ziya River, a main branch of south part of the Hai River. The basin covers 22,814 km^2 and had a population of 15.64 million in 1998. The Fuyang River Basin (FRB) has a temperate monsoon climate and is in a dry sub-humid region. The annual average temperature is about 13°C and the annual mean precipitation for the basin was 543 mm in the period 1956–98. More than 70% of the rainfall occurs between June and September. Table 1 summarises the basic characteristics of the FRB.

Table 1. Basic characteristics of the Fuyang River Basin.

Variables	Values
Total area (km^2)	22814
Total population (million)	15.64
Population density (persons/km^2)	686
Number of major urban centres	4
Number of prefectures	5
Number of villages	9092
Urban population ()	4.37
Rural population (million)	11.27
Per capita water availability (m^3)*	868
Share of agricultural employment (%)	67
Proportion of population living below official poverty line (%)	6
Cultivated area ('000 ha)	1239
Proportion of irrigated area (%)	83
Multiple cropping intensity (sown area/cultivated area)	1.55
Average annual rainfall (mm) (1956–1998)	543
Annual evapotranspiration (mm) (average 1956–1998)	1562
Maximum temperature (°C)(1956–1998)	42.6
Minimum temperature (°C) (1956–1998)	–20
Average temperature (°C) (1956–1998)	13
Average dry months per year (<5 mm rainfall) (1956–1998)	4

Note: If the years are not indicated, the values are for 1998. *Estimated by the authors based on water accounting analysis in the FRB.
Sources: Hebei Provincial Water Resources Bureau and Hebei Provincial Statistic Bureau.

The basin is a slightly more agriculturally and rurally oriented than the rest of the country, with 72% of the population in the rural sector in 1998 (compared with 70% for the nation as a whole). Industrialisation and urbanisation have grown more slowly than in the rest of the country partly due to scarcity of water in this region. Irrigation plays a critical role in the basin's agriculture and has developed faster in the basin than in the rest of Hebei Province and China. Irrigated land share in the FRB reached 83% in 1998 (rising from 69% in 1985), which is much higher than Hebei province (67%) and the average national level (54%) in the same year (State Statistical Bureau 1999). Wheat and maize are the major crops; followed by vegetables, oil crops, soybeans, cotton, tubers and rice.

Hydrological characteristics of the FRB

Per capita water resource availability is less than 400 m^3 in FRB[1], only one sixth of the national average. Shares of groundwater and surface water were 82% and 18%, respectively, in 1998. Agriculture is the largest water consumer but the share of agricultural water use has been declining over time, from 81% in 1993 to 75% in 1998, mainly due to increasing domestic consumption (from 5% to 10%). Limited by many reasons, the share of industrial water use increased only 1% (from 14% to 15% between 1993 and 1998).[2]

With a total length of 403 km in the main river, the Fuyang River has 14 major branches. All of the Fuyang River's branches flow into the main river at Aixinzhuang, Ningjin county in Xingtai prefecture. The surface water outflow from the basin is measured at Aixinzhuang hydrologic station. Figure 1 shows that the outflows from the basin dramatically decreased from an average of more than 500 million m^3 in the 1970s to a discharge of less than 100 million m^3 in the 1980s and 1990s.

Groundwater is the most important water source in the FRB. With the increasing demands of agricultural, domestic and industrial uses for water, groundwater exploitation increased rapidly and the groundwater table (both the shallow and deep tables) has fallen substantially at more than 1 m annually in the past two decades (Figure 2). Due to the over-exploitation of groundwater, cones of depressions have developed in all five prefectures centered in cities. Urbanisation, industry and population growth have also led to increasing surface and groundwater pollution, which further sharpened the water scarcity situation in the FRB.

1. Estimated by local government, based on China's water balance approach which is different from the water accounting analysis used by the authors.

2. In 1998, for the nation as a whole, the shares of agricultural, industrial and domestic uses of water were 69%, 21% and 10%, respectively.

Overview of the Fuyang irrigation district

As one of three large surface-water irrigation systems in the FRB, Fuyang irrigation district (FID) is located in the upstream part of the basin. The district includes 30 townships and 731 villages from 6 counties and Handan City. The maximum irrigation capacity from surface water can reach 43,000 ha. The average annual area irrigated with surface water in the district was 24,000 ha in 1962–98, about 56% of total surface water irrigated areas in FID or 2% of the total irrigated area in the FRB. The total population in FID is 1.26 million, about 8% of the total population in the FRB. The district is more rural oriented, with 77% of the population rural (compared with 72% for the whole basin) in 1998.

Water accounting analysis

Three representative years in the FRB (1993 for a normal year, 1996 for a wet year, and 1998 for a dry year) and in the FID (1996 for a wet year, 1997 for a dry year and 1998 for a normal year) were selected to conduct a water accounting analysis.[3] The results for the normal year in the FRB and FID are presented separately in Tables 2 and 3. The results show that both the depleted fraction of available water and the process fraction of available water are very high, even under the conditions of groundwater overdraft during both the normal and dry years. This suggests that the additional water for further exploitation is very limited.

To achieve sustainable development, the water storage change in the basin over a long period should be zero. In the past, groundwater was over-drawn, resulting in a declining groundwater table and other environmental problems. The current outflow from the basin is insufficient to maintain sustainable development in the downstream regions. Agriculture is the primary water user in the basin. Water available for

3. Based on water accounting approach presented by Molden and Sakthivadivel (1999).

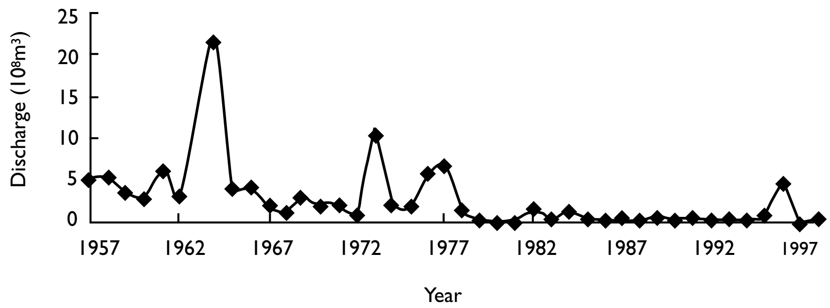

Figure 1. Trend of discharges at Aixinzhuang hydrometric station, 1957–98.

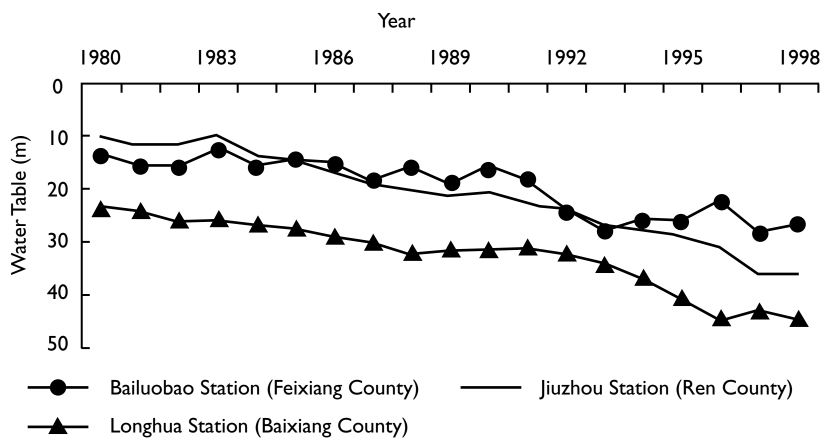

Figure 2. Trends of the groundwater table in Bailuobao, Jiuzhou and Longhua, 1980–1998.

Table 2. Water accounting for a normal year (1993) in the Fuyang River Basin.

Factor	Total	Components
	10^6 m^3	10^6 m^3
Inflow		
Gross inflow	12,290	
Precipitation		12,100
Surface sources from outside basin		190
Storage change	1,053	
Surface		–34
Groundwater		1,087
Net inflow	13,343	
Outflow	54	
Available water	13,298	
Depletive use		
Process depletion	10110	
Irrigated crop evapotranspiration		6,431
Non-irrigated crop evapotranspiration		2,567
Orchard evapotranspiration		689
Industrial uses		330
Domestic uses		93
Non-process depletion	1,500	
Forest evapotranspiration		1,500
Non-beneficial depletion	1,690	
Evapotranspiration from uncultivated lands		1,315
Evapotranspiration from lands lying fallow		259
Free water surface evaporation		116
Total depletion	13,300	
Accounting indicators	**Value**	
Depleted fraction (ratio)		
Gross flow	1.08	
Available water	0.98	
Process fraction (ratio)		
Gross flow	0.82	
Depleted water	0.76	
Available water	0.74	
Productivity of water		
Gross value of production (US$ million)	689	
Gross value of production per unit of:		
Gross inflow (US$/$m^3$)	0.056	
Available water (US$/$m^3$)	0.051	
Crop evapotranspiration (US$/$m^3$)	0.077	

agriculture is expected to decrease in the future as demand for domestic and industrial water uses increases. Generally, industry and domestic sectors have a higher priority for water allocation when there is a water shortage. Increased productivity of water in the agriculture sector will be an important tool for alleviating water shortages in the basin in the future.

Table 3. Government investment share in water projects.

Year	Share of water infrastructure investment over total national infrastructure investment (%)
1951–1957	5.3
1957–1965	7.6
1965–1975	7.0
1975–1982	5.9
1982–1986	2.7
1986–1990	2.2
1990–1997	2.8

Source: Wang (2000).

Increasing evidence in the FRB shows that existing water problems (such as increasing water shortage, decline of groundwater tables, serious water pollution and decline of financial ability of irrigation systems) can be attributed mainly to poor water allocation and management, ineffective water policies and legal instruments, and various water management conflicts among stakeholders and agencies. Any regional and river basin water problems will be influenced by national water management and the institutional environment. In the next section, we discuss national water law, management and institutional arrangement problems, followed by a discussion of relevant water management problems based on our field studies in the FRB and the irrigation system in the basin.

National Water Law System, Management Institutions and Policies

The legal system

Emerging water shortage and environmental problems associated with social and economic development in China have accelerated development of the water law system since the 1980s. Over recent decades, four water laws and nearly 50 water management regulations have been issued. According to contents of these regulations, we grouped the regulations into nine kinds (Figure 3). However, water law and regulations were always too general to be implemented, and amending existing legislation and issuing essential new legislation were very slow, which reflects sharp conflicts among the various stakeholders.

Structure and conflicts of water management

In China, water resources are administered by a nested, hierarchical, administrative system. Figure 4 presents the structure of water management institutions in China. The Ministry of Water Resources (MWR) is at the highest central level, directly under the State Council, with Water Resource Bureaus at the provincial, prefecture and county levels. Water management stations at the township level are the lowest levels of state administration. MWR not only provides technical guidance, issues water policy, law and regulations to sub-national water resource bureaus, but also influences the local bureaus through allocating water infrastructure investment from the central government.

This system of water administration is supplemented by seven river commissions under the MWR. They are responsible for coordinating water allocation among provinces through implementing the policies of MWR. However, these cross-provincial river commissions have little decision-making power (B. Lohmar et al., unpublished paper, 2001). Besides the two main water management systems of MWR, there are several other government authorities such as the ministries, bureaus or agencies of construction, geography and mining, environment protection, energy resource, meteorology, finance, and so on, which have some direct or indirect responsibilities in managing water resources (Figure 4). The diverse functions of water use and the diverse objectives and interests of many water management authorities result in various water management conflicts occurring in rural and urban water use, surface and groundwater balance, water quantity and water quality controls. Water management conflicts between management agencies, horizontal and vertical systems and between the upstream and downstream have not only acceelated water shortages, but also have contributed to poor management, allocation and utilisation efficiency of water resources (Wang and Huang 2000b).

Water management agency reform

In order to strengthen water management and resolve the water conflicts discussed above, China has been trying to reform its water management system since the late 1980s, particularly through a recent reform initiated after the middle 1990s. The reform took a bold move in division of the water management functions among various stakeholders, though the ability to implement the reform is questionable (Wang 2000). By the reform policy, the MWR is provided with an exclusive right to manage water resources. If the reform is successfully implemented, some water management responsibilities currently controlled by other authorities are expected to be transferred to MWR. By the middle 1999, only 7% of the counties in Shanghai, Shananxi, Shanxi, Hebei, Henan, Anhui, Heilongjiang and Shenzhen had established Water Affairs Bureau (WAB) to consolidate the water management system. For the rest of the China, the implementation of the reform has not been initiated.

Water withdrawal permit system, water resources fee and water markets

According to the 1993 regulation on 'Implementation Method of Water Withdrawal Permit System', any organisation or individual drawing over a certain amount of water from a river, lake or groundwater must apply for a water withdrawal permit from the WRBs at various government levels. However, implementation of the above policies has proven to be problematic. The monitoring costs are high and the conflicts among various stakeholders and sectors make it almost impossible to follow the national water permitting system. In China's agricultural sector, there are millions of small farmers and many individually-owned groundwater irrigation wells, so effective implementation of water management arrangements (such as the water withdrawal permit policy and fee collection) at the individual level is a serious problem. Unlike some countries such as America, Mexico and Chile that allow water-rights trading, transferring a water withdrawal permit or water use rights is prohibited in China. But with rising water shortage problems over time, informal groundwater markets have emerged spontaneously in some water shortage areas (Wang 2000).

Water finance and pricing reform

After rural institutional reform was initiated in the late 1970s, the planned financing system in water sector has been gradually decentralised. The major reform has been focused on the responsibility of water management and finance between central and local government and between the government and farmers. The central government has focused its responsibility on the operating costs of the institutions directly under the MWR and the finance for special and nationwide projects such as large flood and drought-control projects. The finance and management of small-scale rural water conservancy projects have been transferred from higher to lower level governments. Since the early 1980s, with financial reform progress, the share of water projects investment in total national infrastructure investment declined from 5–7% to less than 3% (Table 4) between the early 1950s and the early 1990s.

Declining public agricultural and irrigation expenditures attracted attention to the sustainability of agricultural development and the future domestic food supply. Investment policy reviews led to increased investment after the early 1990s (Table 4). However, due to the weaknesses of the fiscal system, the new policy to increase public investment in agriculture and irrigation has hardly been implemented. There are many policies and regulations that have been promulgated regarding the provision of a minimum level of agricultural and public goods, but there is no budget to back them up. Without sufficient funding or staff, policies cannot be effectively carried out.

Although central government has encouraged local governments to increase water prices and improve water charge collection methods such as extending volumetric water pricing, the water charges actually collected can cover only project operation, management, and normal maintenance, while there is no capacity for irrigation management to complete large-scale repatriation, rehabilitation and reconstruction. Further, the share of actual water charge collection is always lower than 70% in most regions (Wang and Huang 2000).

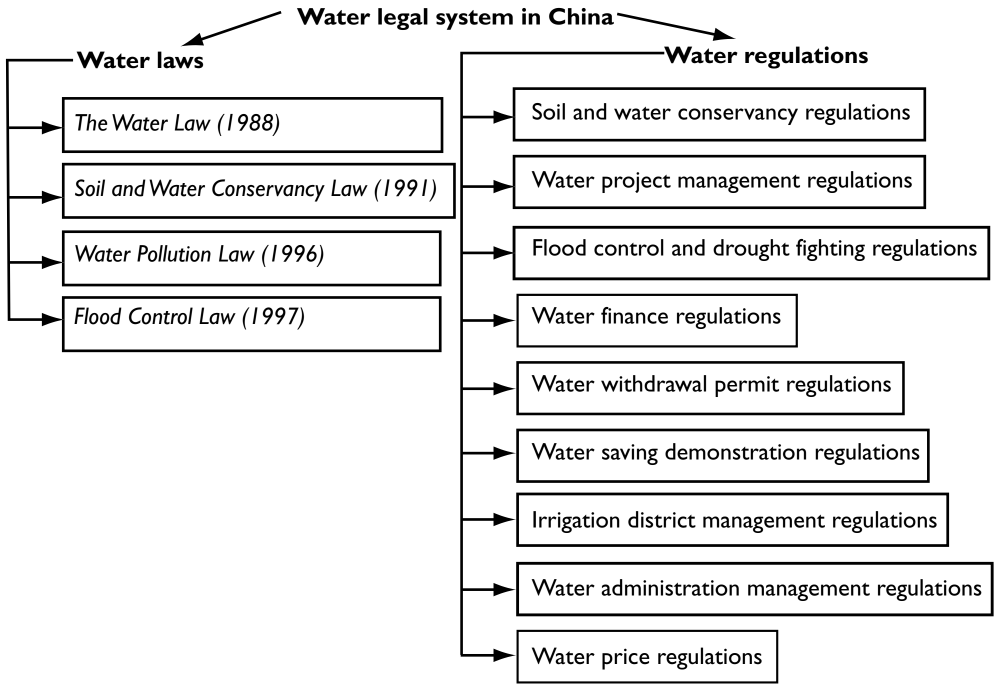

Figure 3. Water legal system in China.

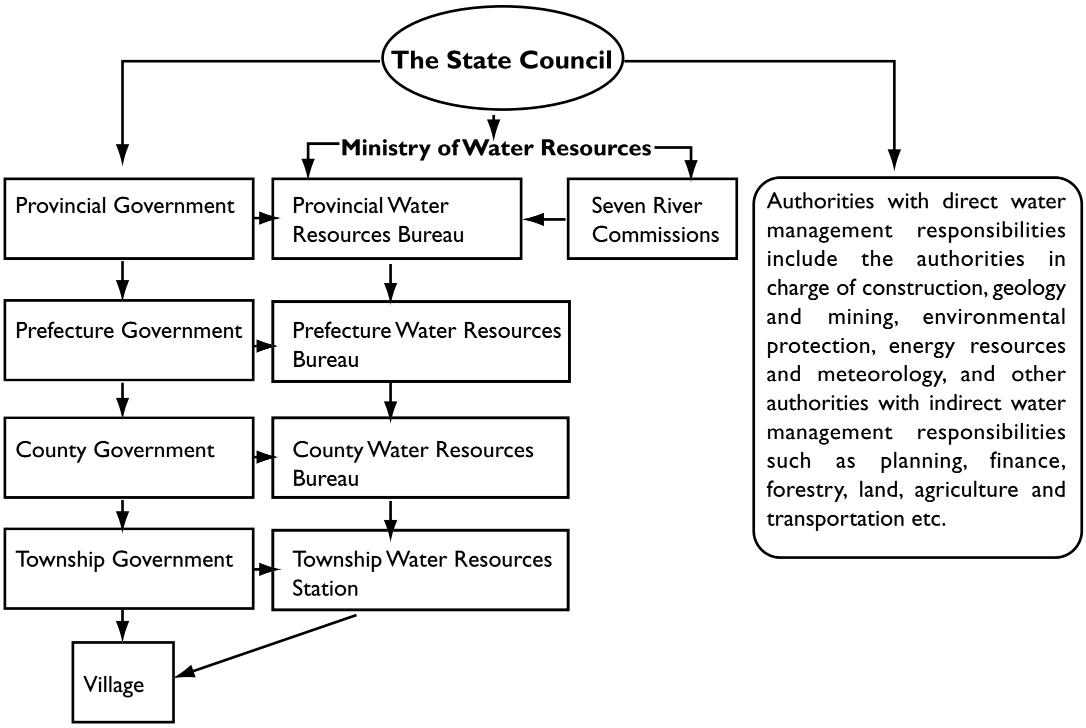

Figure 4. Structure of water management institutions in China.

Water Regulations, Management Institutions and Financing in the FRB

The local governments in the FRB issued water management regulations mainly focusing on water pricing, water finance, water resource fee collection, water withdrawal permit systems and water saving measures. Several water regulations aimed at increasing the efficiency of water were issued earlier than corresponding national regulations, which reflects the water scarcity situation and the attention of local governments to economic measures in solving water shortage problems. On the other hand, the river basin management regulations have not been formulated.

Unlike the seven large river basins, the FRB has no special river basin management organisation. In principle, water in the FRB should be allocated by the Hebei Province Water Resources Bureau (HWRB) through coordinating five prefectures within the basin. In practice, the HWRB has very limited power in allocating water among prefectures and counties in the basin. Water management in the basin is administrated mainly by the local governments at prefecture or county levels. Lack of integrated management in the FRB results in inconsistent local economic structure and water endowment.

In addition to the management conflicts between horizontal and vertical agencies, local water resources bureaus, urban construction bureaus, and environmental protection bureaus among others also have many conflicts in managing rural and urban water, surface and groundwater, water quantity and quality. In order to implement the State Council's 1998 organizational and management reform, local governments in the FRB declared that they would complete the water management reform especially in realising urban and rural integrated water management by the end of 2000. By 1999, about 49% of counties in the FRB have established Water Affairs Bureaus compared with the national level of 7% in the same period (Ministry of Water Resources 1999).

Water Allocation, Finance and Pricing Reform in the FID

Water allocation in the FID

Five seasonal Fuyang River branches flow into the Dongwushi Reservoir, which plays an important role in surface water supply for FID. Table 5 shows that the annual inflow of surface water in the FID has generally been falling and the share of agricultural water use has also decreased over time. Industrial and domestic water uses have priority in water allocation; downstream water users are receiving less and less water.

Water finance in the FID

In 1962, the Management Authority of FID (MAFID) under the Handan prefecture water resources bureau was set up with nine irrigation subdistricts (branches). Government investment was a dominant financial resource for the surface water system of FID before 1981 but has been almost fully replaced by the revenue generated by MAFID (Table 6). Before 1983, all income came from water fee collection, though the amount was very small. With the financial system reform in the water sector initiated after the 1980s and in order to improve the financial capacity for maintaining the surface water system, MAFID started to run its own enterprises and businesses such as fishing, plastic firms and metal processing firms etc. However, the income generated from these commercial activities was not sufficient to offset the decline in government investment (Tables 6 and 7). Our field interviews also reveal that the income from the commercial sources is mainly used to compensate for the lack of core funding for the local staff salaries in the surface water system of MAFID (Wang and Huang 2000).

Before the early 1980s, the farmers' contribution to the surface water system was mainly through their provision of yiwugong (obligatory labour) in the maintenance and construction of water projects at the local community level (Table 6). Yiwugong has declined significantly since the 1980s. On the other hand, the water fees paid by farmers have increased rapidly over the same period. In terms of investment priority, investment in the surface water system has shifted over time, from new construction projects to maintenance.

Water price reform and water fee collection approaches in the FID

Although the local government tried to implement volumetric water pricing for surface water, because of measurement difficulties it has hardly been implemented. At the local level, water fees based on crop areas were collected by village leaders or people appointed by the MAFID. Recently, the water fees have been merged with the other payments that farmers have to make for the services provided by the local village and township, such as education, rural infrastructure development, and other public services, as well as agricultural taxes. In most areas, these merged or aggregated payments are often linked with the government grain procurement system that allows the farmers to pay all these merged fees in kind, in terms of a grain equivalent. In 2000, learning from some other irrigation districts, one sub-district in the FRB established water user associations to overcome the difficulties in collecting water fees and to improve the management of field canals.

Table 8 shows the trends of water prices in both nominal and real (1990) terms for use in industry, domestic water supply and irrigation, for the period 1971–1998. Water prices for various uses were constant until the late 1970s, rising significantly thereafter in nominal terms. Despite the significant rise in water prices in the past three decades, they are still much lower than the true productive value of water. Indeed, water prices in real terms for industrial and domestic uses declined in the first half of the 1990s. While the agricultural water prices kept rising, though at a slower rate after the late 1980s, they were much lower than the prices of water for other uses.

Property Rights Innovation in Groundwater Irrigation

Surface and groundwater irrigation have different management systems. The surface irrigation system has been mostly controlled by the government, such as in FID, though a contract management system was implemented in some periods. Compared with groundwater irrigation, surface irrigation basically has not changed in property rights since the 1980s. We will therefore focus on the evolution of property rights in the groundwater irrigation system. In this section, we present the results of our recent surveys from a randomly selected sample of 30 villages and 87 samples of the groundwater irrigation system[4] in three counties (two in FRB and the other in a nearby basin) of Hebei province.

Investment in groundwater irrigation systems

Groundwater irrigation investment was mainly financed by the local villages and townships, with varying extents of government finance subsidies before the implementation of the household production responsibility system (HRS) initiated in the late 1970s. Farmers always contribute family labour for constructing a groundwater irrigation system. Collective ownership dominated all groundwater irrigation systems. With the implementation of HRS, the declining collective role in the local economy and growing private (farmers) involvement in groundwater irrigation, investment from collectives and government has dropped considerably, while farmers' investment has increased significantly since the early 1980s (Table 9).

Characteristics of property rights innovation

In this study, we divide the groundwater irrigation system into two groups with different property rights: collective and non-collective. For collectively-owned irrigation systems, we further classify them into purely-collectively-owned and quasi-collectively-owned irrigation systems, the latter covering those irrigation systems in which both collectives and farmers or other organisation jointly owned the system. Non-collectively-owned irrigation systems are also classified into two sub-groups: individual privately-owned, and shareholding by several individuals.

The most significant change in property rights in the groundwater irrigation system in our study area has been a shift from collective to non-collective ownership. The share of non-collectively-owned irrigation systems increased from 17% in the early 1980s to 69% in 1998 (Table 10).

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4. A unit of groundwater irrigation system is defined as one tube-well and its facilities.

Table 4. Total annual surface water inflow and allocation in the Fuyang Irrigation District.

Period	Total inflow (million m^3)	Total water use (million m^3)	Water losses in river canal (million m^3)	Water supply for downstream irrigation districts (million m^3)	Share of agricultural water use (%)
1960s	475	190	71	214	52
1970s	398	225	56	117	44
1980s	276	165	45	65	51
1990s	294	183	46	65	36

Source: Management Authority of Fuyang Irrigation District.

Table 5. Investment in surface water systems of the Fuyang Irrigation District**.**

Year	Total investment (million yuan in 1990 terms)	Investment sources (%)			Labour input ('000 days)	Expense shares (%)	
		Government fiscal	MAFID's revenue	Farmers		Maintenance	Construction
1955–58	2.37	96	4	0	70	0	100
1962–69	2.22	96	4	0	593	43	57
1970–79	1.48	68	29	4	3588	40	60
1980–89	1.23	69	32	0	190	29	71
1990–98	0.62	0	100	0	2	100	0
1955–98	1.46	74	25	1	1044	47	53

Source: Management Authority of Fuyang Irrigation District (MAFID).

Table 6. Income and expenditure in the surface water system of Fuyang Irrigation District Management Division.

Year	Income (million yuan)	Income sources (%)		Expenditure (million yuan)	Expenditure shares (%)		
		Water fee	Others*		Engineering	Management	Others[a]
1962–1969	0.25	100	0	0.18	56	44	0
1970–1979	0.45	100	0	0.37	44	56	0
1980–1989	4.42	96	4	2.87	7	10	83
1990–1998	6.19	93	7	5.63	12	15	72
1962–1998	2.88	94	6	2.28	13	16	72

[a] = incomes through operating enterprises in the Fuyang Irrigation District.
Note: Income and expenditure are real values in 1990 prices.
Source: Management Authority of Fuyang Irrigation District.

Within the collective property right system, purely-collectively-owned irrigation systems have been gradually replaced by quasi-collective systems (Table 10). The non-collectively-owned groundwater irrigation systems were dominated by the farmers' shareholding in the initial stage of property right changes due to credit constraints on individual farmers. But the proportion of individual privately-owned irrigation systems have been growing rapidly since the early 1990s, increasing from 1% in 1990 to 14% in 1998.

Determinants and impacts of new property rights

Econometric analyses of the determinants of property rights innovation[5] show that the non-collective property right of the groundwater irrigation system is induced by many factors, including changing resource endowments, environmental stress, weakening local collective economy, market development, improving human capital, and financial policies (Table 11, and Wang et al. 2000). Among these factors, increasing water scarcity, over-exploitation of groundwater, and increasing population pressure are major factors that led to rapid expansion of non-collective groundwater irrigation activities.

Econometric results (Table 12) show that in case 1 (dummy variables of property right are divided into collective and non-collective), the coefficient of non-collective property right is statistically significant and positively correlated with technical efficiency. It indicates that the changes of property rights in favour of non-collective and market-oriented mechanisms in irrigation have significant impacts on the technical efficiency[6] of the water supply sector after allowing for all other impacts[7] (Wang and Huang 2000). Further, introduction of non-collective property rights for groundwater irrigation was also found to have statistically significant impacts on cropping patterns and agricultural production (Xiang and Huang 2000). In particular, the expansion of private or non-collectively-owned irrigation stimulates cropping pattern changes in favour of high-value cash crops and against grain crops. This change raises farmers' incomes as the former are more profitable and the additional water is available for later crop cultivation through the increase in water-use efficiency, due to the irrigation property right changes.

Policy implications

The above findings have strong policy implications for raising water productivity and farmers' incomes. The ongoing expansion of private and shareholding groundwater irrigation should be encouraged and integrated into the government irrigation investment programs. The current government fiscal and financial/credit policies that are in favour of collectively-owned irrigation, as well as the large irrigation projects owned by the state, should be revisited and reevaluated.

However, our study also warns that, if water prices do not fully reflect the marginal value of water use (including externalities affecting other water users), then property rights innovation toward privatisation might lead to over-exploitation of groundwater and water table declines. Therefore, in order to promote sustainable development of water resources, future water resources policy should emphasise property right innovation, rationalising water prices and better groundwater management institutions.

5. Data from 30 sample villages are used in this model.

6. Technical efficiency is defined as ratio of observed water output to potential water output (water frontier output).

7. Data of 87 samples of groundwater irrigation system are used in estimation.

Table 7. Delivery prices of surface water from water suppliers in Fuyang Irrigation District.

Year	In nominal prices (yuan/m^3)			In 1990 real prices (yuan/m^3)		
	Industry	Domestic	Irrigation	Industry	Domestic	Irrigation
1971	0.006	0.001	0.002	0.013	0.003	0.004
1975	0.006	0.001	0.002	0.013	0.003	0.004
1980	0.010	0.002	0.003	0.019	0.004	0.006
1985	0.050	0.010	0.007	0.081	0.016	0.011
1990	0.232	0.051	0.019	0.232	0.051	0.019
1995	0.278	0.064	0.054	0.161	0.037	0.032
1998	0.365	0.128	0.069	0.204	0.072	0.039

Source: Management Authority of Fuyang Irrigation District .

Table 8. Groundwater irrigation investment in the 30 sample villages in Feixiang, Yuanshi and Qinglong counties, Hebei Province.

Year	Sources of groundwater irrigation investment (%)					Total investment (million yuan)[a]
	Total	State	Collective	Farmers	Others	
1983	100	21	12	67	0	203
1990	100	10	11	69	11	85
1998	100	3	5	92	0	170

[a] real price in 1990. Note: Feixiang and Yuanshi counties locate in FRB, Qinglong county locates in the neighboring basin of FRB.
Source: Author's surveys in 30 randomly selected villages from three counties of Hebei Province.

Table 9. Changing structure (%) of property rights in groundwater irrigation system, 1983–98.

Year	Collective versus non-collective		Within collective		Within non-collective	
	Collective	Non-collective	Pure	Quasi	Shareholding	Private
1983	83	17	52	48	100	0
1990	56	44	24	76	99	1
1997	32	68	16	84	87	13
1998	31	69	18	82	86	14

Source: Field survey in 30 villages in three counties, Hebei Province.

Table 10. Determinants of property rights innovation in groundwater irrigation.[a]

Variables	Share of non-collective property right of groundwater irrigation system (%)		
	OLS		Random effect model
	Case 1[e]	Case 2[e]	
Constant	–132.022	–404.156	–111.367
	(–0.69)[b]	(–4.55)***	(–1.99)**
Water resources endowments			
Groundwater table level in the last year (log)	4.817	66.031	13.246
	(1.39)	(3.33)***	(2.64)***
Share of surface water use in irrigation (%)	0.430	0.435	0.455
	(2.72)***	(3.07)***	(3.21)***
Environmental stress			
Per capita cultivated area (log)	–3.262	–83.075	–31.740
	(–0.27)	(–2.54)**	(–1.90)**
Local community economic power			
Per capita real net income of farmers (log)	–9.370	–11.570	–11.740
	(–1.11)	(–0.91)	(–1.23)
Per capita income of village collective (log)	–4.074	1.340	0.250
	(–1.82)*	(0.72)	(–0.13)
Human capital in local community			
Share of agricultural labors who received middle school or higher education (%)	1.979 (5.54)***	0.038 (0.07)	1.595 (4.06)***
Policy dummy variables			
With fiscal subsidies for water project	9.359	13.479	13.873
	(1.25)	(2.06)**	(2.12)**
With subsidised loan for water project	–27.680	–62.107	–30.018
	(–4.14)***	(–2.10)**	(–2.90)***
Road condition dummy	13.383	21.947	19.037
	(1.84)**	(2.24)**	(2.29)**
29 village dummy variables[c]	_[d]	omit	–
R^2	0.458	0.833	0.619
Adjusted R^2	0.413	0.755	–
F	10.31	10.63	–
Chi^2	–	–	137.77
Degrees of freedom	110	81	110

[a] The sample size is 120.
[b] Number in parentheses are t statistics (case 1 and case 2) or z statistics (random effects model); *, ** and ***represent statistically significant at 10%, 5% and 1%, respectively.
[c] Coefficients for village dummy variables have not been listed.
[d] – indicates the variable has not been included in model.
[e] Case 1 does not include the village dummy variables while case 2 includes village dummy variables.

Table 11. Estimated results of stochastic water production frontier model.

Variables	Water production (log)[a]			
	Case 1[d]		Case 2[d]	
	Coefficient	t statistic	Coefficient	t statistic
Constant	2.410	(16.24)***[b]	2.408	(16.79)***
Fixed cost (log)	0.080	(2.85)***	0.081	(2.88)***
Variable cost (log)	0.255	(5.95)***	0.254	(6.00)***
Labour (log)	0.389	(7.16)***	0.389	(7.38)***
Average water table level (log)	0.049	(0.92)	0.056	(1.04)
Dummy for 1997	0.034	(1.52)	0.033	(1.46)
Dummy for 1998	0.026	(1.21)	0.027	(1.23)
County dummy: Feixiang	–0.196	(–2.51)**	–0.208	(–2.64)***
County dummy: Yuanshi	–0.106	(–2.02)**	–0.110	(–2.07)**
Variables influencing technical efficiency				
Constant	0.459	(7.77)***	0.460	(8.38)***
Dummies for property right				
Non–collective	–0.084	(–2.44)**	–[c]	–
Shareholding	–	–	–0.088	(–2.87)***
Private	–	–	–0.028	(–0.40)
Dummy for management with bonus	–0.085	(–1.99)**	–0.101	(–2.59)***
Irrigation system scale				
Annual maximum irrigated area (ha)	–0.023	(–12.57)***	–0.022	(–13.89)***
Management ability of manager				
Schooling years (years)	0.001	(0.16)	0.001	(0.17)
Irrigation system age				
Founding years (years)	–0.014	(–2.19)**	–0.013	(–2.19)**
δ^2	0.019	(4.64)***	0.018	(6.12)***
Γ	0.912	(24.98)***	0.907	(26.56)***
Maximum likelihood value	155.09		155.72	
Average value of technical efficiency	0.818		0.819	

[a] The sample size is 189.

[b] *, ** and *** represent statistically significant at 10%, 5% and 1%, respectively.

[c] - indicates the variable has not been included in the model.

[d] Property right dummy variables in case 1 are divided into two kinds: collective and non-collective; while those in case 2 are divided into three kinds: collective, shareholding and private.

Concluding Remarks

Declining groundwater levels, reduced surface water discharges and increasing water competition among stakeholders with growing water demand are facing China, one of the most water-short countries in the world. If these trends continue and the government does not respond them with proper policies in the future, water shortage could threaten China's economically and environmentally sustainable development.

Although limited water endowment is one of the important reasons for the expanding water demand and supply gap, the existing legal system, regulations, management and other water related policies add to the unbalanced and unsustainable use of water in China, particularly in the northern regions. The water management and organisational conflicts between rural and urban water allocation, between surface and groundwater, and between horizontal and vertical management authorities will hardly be solved if the system is not reformed. A better-enforced system of laws and regulations, and a more effective institutional setting that facilitates the implementation of integrated water management at national, regional and water basin levels needs to be established.

Although the seven large-river commissions were established to coordinate water allocation and flood control across provinces, because of their limited power, the impacts of these commissions are more on flood control than water allocation. Generally, there is no inter-regional water management authority in the small water basins. The local governments based on administrative jurisdictions often separately manage the water in the small water basins. Within the administrative jurisdictions, water supply and demand are controlled and managed by too many authorities that have different interests and therefore result in various conflicts in balancing water use in the region. Increasing conflicts, unbalanced and inefficient water allocation among sectors and between upstream and downstream within river basin has made integrated river basin management essential.

Although central and local governments have successfully developed surface and groundwater resources through mobilising all possible financial and human capital by administrative measures that greatly supported national and local social and economic development, there is growing evidence that administrative measures alone cannot solve increasing water shortage problems. Market oriented water management measures such as rational water price, water market, water rights[8] transfer and property rights innovation for water facilities should be emphasised and introduced into central and local water management systems.

Our study on property right innovation also suggests that the private and shareholding groundwater irrigation system can improve the efficiency of water use. The existing government fiscal and financial policies in irrigation investment need to be revised in order to encourage the development of this market oriented irrigation management system.

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Property Rights and Externalities in Water Trade

Anna Heaney and Stephen Beare*

Abstract

As water becomes a more scarce resource in the Murray–Darling Basin, the need to establish an efficient water market will become increasingly important. However, introducing trade with poorly defined property rights may generate externalities that impose indirect costs or benefits to water users and the environment, leading to an inefficient allocation of water resources. This paper examines the importance of establishing property rights to return flows from irrigation.

Return flows from irrigation contribute a substantial proportion of river flows and water entitlements held by downstream users in the Murray River system. Return flows also have a significant impact on water quality as a large proportion of the salt load in the Murray River comes from the discharge of saline drainage and groundwater flows from irrigation. Water trade between irrigation regions can alter the pattern of return flows, imposing indirect benefits and costs on downstream users and the environment. If these indirect benefits and costs are not internalised in the institutional arrangements that govern trade, the full, net economic gains from trade will not be realised.

A simulation model has been developed at the Australian Bureau of Agricultural and Resource Economic to evaluate both the internal and external costs and benefits of trade in irrigation water in the Murray–Darling Basin. The model incorporates the relationships between land and water use, vegetation cover, surface and groundwater hydrology and agricultural returns. The model consists of a network of land-use units linked through overland and groundwater flows. Land-use units are defined according to the characteristics of the groundwater system and each unit is managed independently to maximise returns given the level of salinity of available land and water resources, subject to any land use constraints.

The model is used to simulate bilateral trade between several irrigation areas in the Murray–Darling Basin. The results indicate that water trade can generate significant external benefits and costs to downstream water users. As these impacts vary continuously along the river depending on the source and destination of the trade, the transaction costs associated with fully internalising the externalities through site-specific conditions attached to trade are likely to be prohibitively high. However, administering taxes and subsidies or water exchange rates for trades between irrigation regions may lead to a more efficient allocation of water.

In the mid-1990s, the Council of Australian Governments (COAG) recommended a number of water reforms, including a cap on water use and the development of water property rights and the establishment of markets for water trading (COAG 1994). One objective was to encourage use of water such that the highest total benefit from all consumptive (for example, irrigation) and nonconsumptive uses (for example, environmental flows) is obtained. However, the physical and economic environment in which water property rights are being introduced is complex. Irrigation affects the volume and quality of water available to downstream users and the riverine environment more generally. Introducing trade with poorly defined property rights may generate externalities that impose indirect cost or benefits on water users and the environment, leading to an inefficient allocation of water resources.

One aspect of water rights that may warrant considerably more attention in the Murray River system is irrigator rights to use and discharge return flows. At present these rights are not clearly defined. Return flows from irrigation represent a substantial proportion of river flows and have a significant impact on water quality in the Murray River. Water trade can alter the pattern of return flows affecting the volume

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and quality of downstream flows. This may affect the entitlements and productivity of water available for downstream users as well as the riverine environment.

The main quality issue in the Murray River system has been increasing river salinity. A salinity audit, released by the Murray–Darling Basin Ministerial Council in 1999, projected that salt mobilisation in the basin would double from 5 Mt a year in 1998 to 10 Mt in 2100. The audit also reported that the average salinity of the Murray River at Morgan, upstream of the major offtakes of water to Adelaide, South Australia, will exceed the 800 EC[1] World Health Organization threshold for desirable drinking water quality in the next 50–100 years (MDBMC 1999). A substantial proportion of the salt load in the Murray River comes from the additional discharge of saline groundwater flows from irrigation.

[1] The most widely used method of estimating the salinity concentration of water is by electrical conductivity. To convert 1 EC to mg/L total dissolved salts, a conversion factor of 0.6 generally applies.

As a part of a project to evaluate land and water management options in the Murray–Darling Basin, a simulation model was developed to examine the impact of irrigation and river flows and salinity. Within the modelling framework, the interrelationships between land and water use, vegetation cover, surface and groundwater hydrology and agricultural returns are represented. The model, described in more detail in Bell and Heaney (2000), was developed at the Australian Bureau of Agricultural and Resource Economics (ABARE) in cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It was initially used to estimate the benefits of improved irrigation efficiency as a tool for salinity management in the Riverland region of South Australia (Heaney et al. 2001). For this paper, the model was extended to examine the impact of water trade in the irrigation areas of the Murray River and its major southern tributaries. The geographic area under consideration is shown in Figure 1.

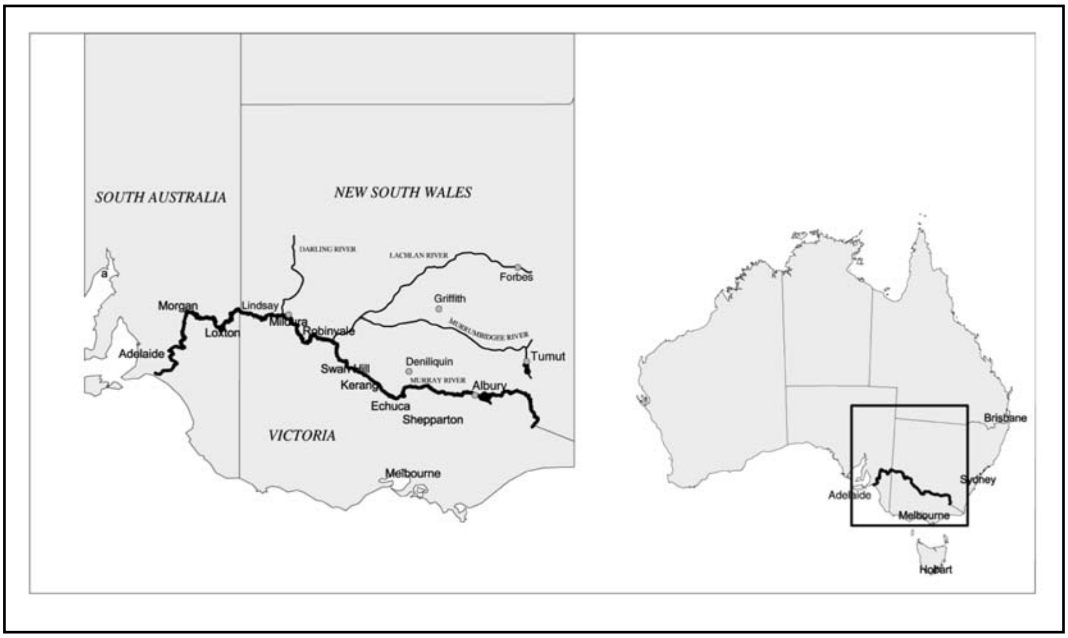

Figure 1. Major irrigation areas in the southern Murray Darling Basin.

Background

The development of irrigation in the Murray–Darling Basin was supported by public investment in infrastructure that began in the early 1900s. Two objectives of this investment were to increase agricultural exports and to move people back to rural Australia. This infrastructure has supported a large amount of low returning irrigated activities with low rates of irrigation efficiency. As irrigation water allocations were initially tied to the land, this inefficiency was preserved as these restrictions prevented water being redirected to higher valued uses. However, this did not limit the use of water for irrigation purposes; water diversion from river systems in the Murray–Darling Basin rose dramatically between the 1950s and mid-1990s. In 1995, an audit of water use in the basin showed that if the volume of water diversions in the basin continued to increase, river health problems would be exacerbated, the security of water supply for existing irrigators in the basin would be diminished, and the reliability of water supply during long droughts would be reduced. Consequently, a cap was imposed on the volume of water that could be diverted from the rivers for consumptive uses. While this cap limits further increases in water diversions, it does not constrain new developments, provided their water requirements are met by using current allocations more efficiently or by purchasing water from existing developments.

The cap on diversions has effectively made water, as opposed to storage capacity and delivery infrastructure, the scarce resource thus creating the need for an effective water market. However, there have been several impediments to the formation of a fully functioning water market and, to date, there has not been a substantial change in water use through trade. Within the Goulburn–Murray region, temporary and permanent trade accounted for around 5% of total allocations in 1996–97 (Earl and Flett 1998). Trade between irrigation regions, however, has been very limited, with some districts refusing to allow water to be traded out.

Most of the impediments to trade can be attributed to changing from a system of water allocations and administered prices to one based on water rights. This change led to equity issues associated with the redefinition of rights and the sovereign risks associated with these rights. There are various associated with how private water rights are defined that will affect the potential gains from trade. Many of these issues have been discussed in economic literature.

Dudley and Musgrave (1988) considered the potential advantages of defining property rights in terms of capacity shares on regulated river systems in Australia. The work demonstrates the link between access rights and storage infrastructure. Beare and Bell (1998) demonstrated that access rights to infrastructure are also an important aspect of the value of a water right when the timing of delivery is constrained by the capacity of the delivery system. It has also been noted that failure to link water rights to the costs of infrastructure can lead to the stranding of irrigation assets. Hence, while trade within irrigation areas is becoming established, there has been a reluctance to allow trade between regions that do not share a substantial proportion of their delivery infrastructure.

In a study of an irrigation region near the Murrumbidgee River, Hafi et al. (2001) examined the importance of accounting for conveyance losses in water allocations. Water entitlements in Australia are commonly defined at the point of use. Trading water rights defined at the point of use, as opposed to the source, generates externalities in that all users who derive their entitlements from the source share the conveyance losses or gains resulting from trade.

Return Flows, Externalities and Trade in Irrigation Water

Return flows consist of surface run-off from flood irrigation, irrigation drainage and groundwater discharge from irrigation areas that reach the Murray River system. Water trade affects return flows that, in turn, affect the quantity and quality of water used downstream. Reflecting the large volume of water that is diverted from the Murray River and its tributaries in the upstream irrigation areas and relatively low rates of irrigation efficiency, return flows form a substantial part of water available for downstream users. Further, return flows from irrigation areas with relatively low underlying groundwater salt concentrations may provide dilution flows downstream. In that case, a reduction in return flows from upstream irrigation areas may increase the salinity of water supplies downstream, imposing costs on downstream users. Irrigators presently hold an implicit right to return flows in that they can trade water without consideration of the downstream externalities. Undertaking these actions without explicit recognition of the downstream impacts generates extern-alities and may lead to an inefficient allocation of water.

These externalities have implications for both consumptive uses and environmental flows. For consumptive use, rights to return flows are an equity, as opposed to an efficiency, issue so long as these rights are well defined. However, as irrigators are not required to account for a loss in return flows as a result of their actions, reductions in the volume of return flows are simply absorbed as an additional diversion imposed above the cap, which may be at the expense of desired environmental flows. Hence, the balance between rights to consumptive use and environmental flows needs to be specified with explicit consideration given to rights to return flows.

However, a significant efficiency issue exists with the impact of return flows on water quality—in particular, the salt concentration of surface water flows. The extent to which return flows affect water quality depends on several factors, including groundwater recharge rates and the groundwater salinity underlying the irrigation areas. Soils throughout most of the irrigation areas in the southern Murray–Darling Basin are shallow. The deep percolation of irrigation water through the soil has led to a large increase in the rate of recharge into the groundwater system. The volume of water entering the groundwater system is higher in areas with low rates of irrigation efficiency. Increased groundwater recharge has led to rising watertables and increased groundwater discharge. Groundwater discharge transports salt to the river by direct seepage or by surface discharge that eventually reaches the river system. The volume of salt transported to the river depends to a large extent on the salinity of the groundwater. The salinity of groundwater discharge in the Murray River and its tributaries is generally low in the upland catchments. Groundwater salinity levels tend to increase moving downstream and reach levels approaching seawater in low-lying regions of South Australia.

The associated increases in the levels of stream salinity in the Murray River can be seen in Figure 2. Water trade may have an impact on river salinity. For example, trade that moves water from an irrigation area with relatively low recharge rates and low groundwater salinity to a downstream irrigation area with high recharge rates and high groundwater salinity can produce a series of impacts on water quality. Immediately downstream of the seller, the transfer may increase stream flows and reduce salt concentration in the Murray River. However, as recharge rates are higher in the downstream area, surface run-off will be lower, reducing the volume of return flows available downstream of the buyer. Further, as groundwater salinity is higher downstream, salt concentrations will be increased as more salt is transported to the river system.

The change in the level of discharge of saline groundwater due to irrigation has important spatial as well as temporal characteristics that make it difficult

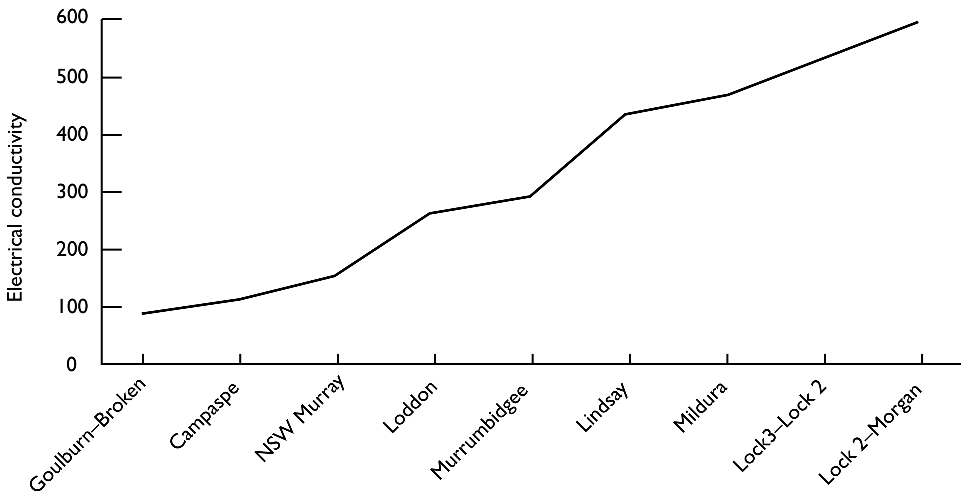

Figure 2. Salt concentration of the Murray River at tributary confluences, 2000.

to internalise the downstream benefits and costs associated with a change in irrigation practices. As the level of salinity in groundwater discharge is location specific, similar irrigation application rates and levels of irrigation efficiency can have substantially different impacts on the level of salt mobilised and the concentration of river system. Hence, a change in location of irrigation through water trade should be related to changes in return flows and salt loads. Externalities associated with site-specific sources and impacts of effluent discharge have received considerable attention in economic literature on pollution abatement (Montgomery 1972; Atkinson and Tietenberg 1987; Malik et al. 1993). Considering the problem in this context helps to illustrate the need to develop appropriate institutional arrangements to achieve efficient allocation of water.

The impact of saline groundwater discharge depends on the location of the source. Generally, upstream irrigators will affect a greater number of assets than downstream irrigators and hence have a higher marginal return from a given level of abatement. In addition, downstream impact will vary from location to location due, for example, to differing salt tolerance of irrigated crops or differing industrial uses. The benefits of a reduction in salinity need to be accounted for in terms of a specific set of downstream sites affected by the change.

In considering emissions permits, Montgomery (1972) established that a separate property right must be defined in terms of the damages generated from a specific source at each affected site downstream to achieve an economically efficient outcome. However, a market solution based on a set of site-specific (spatially differentiated) tradeable property rights, such as a salinity mitigation credit, faces three problems. First, downstream benefits are non-appropriable (the right is non-exclusive). If an individual cannot capture the benefit of an upstream investment in irrigation efficiency, private markets cannot function efficiently (Hartwick and Olewiler 1986). Second, there is considerable uncertainty associated with the level and timing of impacts of an upstream investment in improved irrigation efficiency. When individuals lack information on how upstream activities impact on downstream users, a market may not operate efficiently (Hartwick and Olewiler 1986). Third, several authors have noted that, while a system of traded spatially specific property rights may be a first best policy in theory, the potential complexity and costs of transactions mean that it is not practical to implement (Atkinson and Tietenberg 1987; Stavins, 1995; Hanley et al. 1997).

Given the complications associated with implementing a spatially differentiated salinity credit scheme, a partially differentiated or undifferentiated scheme may be an effective second-best solution. An example may be allowing trade in salinity mitigation credits between irrigation areas as opposed to individual irrigators. Trading arrangements may be supplemented by administered restrictions such as trading ratios or exchange rates between irrigation areas (Malik et al. 1993). However, the potential benefits from any specific intervention will depend on the physical and economic characteristics of the problem.

The potential impact of water trade on salinity has been considered in the Murray River system (MDBC 2001). The Murray–Darling Basin Salinity Management Strategy requires that the salinity impacts of interstate water be accounted for by a system of State-level debits or credits. In Victoria, high impact areas have been identified. and water trade into these areas has been prohibited. In addition, a levy has been introduced on water transferred into the Sunraysia district in the Victorian Mallee near Mildura (Young et al. 2000).

However, there is considerable variation in the indirect effects of changes in return flows between regions and States. An objective of the work presented in this paper is to estimate the internal and external benefits arising from trade. The results are intended to provide an indication of the potential economic benefits of developing a consistent institutional framework to account for return flows. These benefits could include direct economic gains from, for example, charges that reflect the cost of changes in river salinity, as well as providing environmental benefits at least cost.

Model Specification

Within the modelling framework, economic models of land use are integrated with a representation of hydrological processes in each catchment. The hydrological component incorporates the relationships between irrigation, rainfall, evapotranspiration and surface water run-off, the effect of land-use change on groundwater recharge and discharge rates, and the processes governing salt accumulation in streams and soil. The interactions between precipitation, vegetation cover, surface water flows, groundwater processes and agricultural production are modelled at a river reach scale. In turn, these reaches are linked through surface and groundwater flows. In the agroeconomic component of the model, land use is allocated to maximise economic return from the use of agricultural land and irrigation water. Incorporated in this component is the relationship between yield loss and salinity for each agricultural activity. Thus, land use can shift with changes in the availability and quality of both land and water resources. The modeling approach is described in more detail in Bell and Heaney (2000) and Bell and Klijn (2000).

The rate at which salt stored in groundwater is transported to the river system depends on, among other things, the size of an irrigation development, irrigation efficiency, the underlying geology of the irrigated area, and the distance between the irrigation development and the river valley. The methodology developed to assess the impact of changes in these parameters on salt loads in South Australian irrigation developments (Watkins and Waclawik 1996; AWE 1999) has been adapted to catchments in Victoria and New South Wales. Two specific changes were made. First, drainage schemes that discharge into the river system in many irrigation areas were incorporated. In general, flows from these drains carry surface water run-off from rainfall, flood irrigation and groundwater discharge. Second, the Murray River meanders in the Victorian Mallee (between the confluence of the Murrumbidgee and the South Australian border shown in Figure 1). As a consequence, in some irrigation areas, groundwater may be either flowing toward or away from the river affecting the level of saline stream discharge. This was incorporated by allowing a fraction of the recharge to move into a deep aquifer that does not discharge into the Murray River.

As the clearance of native vegetation has contributed to increased recharge in the dryland agricultural areas in the upland reaches of the catchments, the model also has land management units for rain-fed activities. However, as these areas are not affected by irrigation, they will not be considered here.

Agroeconomic component

The management problem considered in the agroeconomic component of the model is that of maximising the economic return from the use of agricultural land by choosing between alternative steady-state land-use activities in each year. There are five land-use activities: irrigated crops, irrigated pasture, irrigated horticulture, dryland crops and dryland pasture.

Each region is assumed to allocate its available land each year between the above activities to maximise the net return from the use of the land in production, subject to constraints on the overall availability of irrigation water from rivers, sw^*, and from ground water sources, gw^*, and suitable land, L^*:

$$\max \frac{1}{r}\sum_j p_j x_j\left(L_j, sw_j, gw_j\right) - csw\sum_j sw_j - cgw\sum_j gw_j \quad (1)$$

subject to

$$\sum_j sw_j \le sw^*, \sum_j gw_j \le gw^* and \sum_j L_j \le L^* \quad (2)$$

where x_j is output of activity j, Lj is land used in activity j, sw_j is surface water and gw_j is groundwater used for irrigation of activity j, r is a discount rate, and csw is the unit cost of surface water used for irrigation and cgw is the unit cost of groundwater used for irrigation. The net return to output for each activity is given by p_j and is defined as the revenue from output less the cost of inputs, other than land and water, per unit of output.

For each activity, the volume of output depends on land and water use (or on a subset of these inputs) according to a Cobb-Douglas production function:

$$\begin{aligned} & x_j = A_j L_j^{\alpha_{Lj}} sw_j^{\alpha_{swj}(t)} gw_j^{\alpha_{gwj}} \\ & \text{and } 0 < \alpha_{Lj} + \alpha_{swj} + \alpha_{gwj} < 1 \; for \; j = 1,2,3 \\ & \text{else} \\ & x_j = A_j L_j^{\alpha_{Lj}} \\ & \text{and } 0 < \alpha_{Lj} < 1 \; for \; j = 4,5 \end{aligned} \quad (3)$$

where A_j, $\alpha_{Lj,}$ α_{swj} and α_{gwj} are technical coefficients in the production function. Note that the technical coefficients on surface irrigation water are time-dependent to capture the impact of changes in salt concentration in the Murray River.

The costs to irrigated agriculture and horticulture resulting from yield reductions caused by increased river salinity are modelled explicitly. The impact of saline water on the productivity of plants is assumed to occur by the extraction by plants of saline water from the soil. The electro-conductivity of the soil, *EC*, reflects the concentration of salt in the soil water and reduces the level of output per unit of land input (land yield) and per unit of water input (water yield). This is represented by modifying the appropriate technical coefficients, α_{swj}, in the production function for each activity from the level of those coefficients in the absence of salinity impacts, that is:

$$\alpha_{swj}(t) = \frac{\alpha_{swj}^{\max}}{1 + \exp\left(\mu_{0j} + \mu_{1j} EC\right)} \quad (4)$$

where μ_0 and μ_1 are productivity impact coefficients determined for each activity and α_{swj}^{max} is the level of the technical coefficient in the absence of salinity.

Hydrological component

There are two parts to the hydrological component of the model. The first is the distribution of precipitation and irrigation water between evaporation and transpiration, surface water run-off and groundwater recharge. Evaporation and transpiration are determined as a function of precipitation and ground cover, as well as irrigation application rates and efficiency. Water application rates in the southern Murray–Darling Basin for horticulture are around 10 ML/ha/year, equivalent to 1000 mm of precipitation, whereas average application rates for pasture are between 4 and 6 ML/ha/year (Gordon et al. 2000). Irrigation efficiency is defined as the proportion of irrigation water applied that is returned to the atmosphere through evaporation and transpiration. In horticultural areas such as western Victoria and the South Australian Riverland, irrigation efficiency can approach 75–80% for horticulture (A. Meisner, Department of Environment, Heritage and Aboriginal Affairs, pers. comm., November 2000). In areas where there is widespread use of flood irrigation on pasture, irrigation efficiency is of the order of 50%.

The excess of precipitation and irrigation water over evaporation and transpiration is split between surface water run-off and groundwater recharge using a constant proportion (recharge fraction). The volume of irrigation water entering the groundwater system depends largely on terrain and soil structure. Irrigation areas are generally located in flat terrain leading to reduced run-off and consequently higher recharge fractions. On heavier, less permeable soils in the upland river catchments, recharge fractions are assumed to be in the range of 50–60%. On the sandier more permeable soils in the South Australian Riverland recharge fractions are 100%.

Some soils have intervening layers of clay that impede drainage into the groundwater system. Tile drainage is used in these areas to avoid waterlogging. Tile drainage is represented in the model though a combination of an increase in irrigation efficiency where drainage is re-used or allowed to evaporate, or as a return flow to the river system. Saline groundwater discharge can be intercepted through groundwater pumping for subsequent disposal in evaporation ponds. In some irrigation areas, such as the South Australian Riverland, there is groundwater discharge to the flood plains that is mobilised in flood events and does not contribute to the problem of high salt concentrations. Reductions in average saline discharge from these effects are accounted for in calculating river salt and water balances.

The second part of the hydrology component is the determination of groundwater discharge. The equilibrium response time of a groundwater flow system is the time it takes for a change in the rate of recharge to be fully reflected in a change in the rate of discharge. The equilibrium response time does not reflect the actual flow of water through the groundwater system but the transmission of water pressure. The response time increases rapidly with the lateral distance the water flows in areas such as the South Australian Riverland owing to the flat terrain and resultant low hydrological pressure.

Assuming the contributions of recharge are additive and uncorrelated over time, it is possible to model gross discharge directly, thereby avoiding the need to explicitly model groundwater levels. In the approach adopted here, total discharge rate D in year t is a logistic function of a moving average of recharge rates in the current and earlier years according to:

$$D(t) = R(0) + \sum_{i=t-m}^{t} \frac{R_{(i)} - R(i-1)}{1 + \exp\left[\left(v_{half} - i\right) / v_{slope}\right]} \quad (5)$$

where *R(0)* is the initial equilibrium recharge rate, m is the number of terms included in the moving average calculation, and v_{half} and v_{slope} are the time response parameters. The moving average formulation allows the accumulated impacts of past land-use change to be incorporated as well as the modelling of prospective changes.

As the distance from the river increases, the time before a change in the level of recharge is fully reflected in the level of groundwater discharge increases substantially. Irrigation areas in western Victoria and the South Australian Riverland were divided into three land-use bands according to distance from the river. Typical response profiles for the three land use bands are shown in Figure 3. Parameters for the groundwater response functions in these irrigation areas were obtained from Watkins and Waclawik (1996). Similar groundwater response functions were assumed for the remaining irrigation areas based on discussions with CSIRO and other hydrologists. Response times were assumed to be longer the larger the irrigation area. However, in areas with substantial areas of high watertables, response times were reduced.

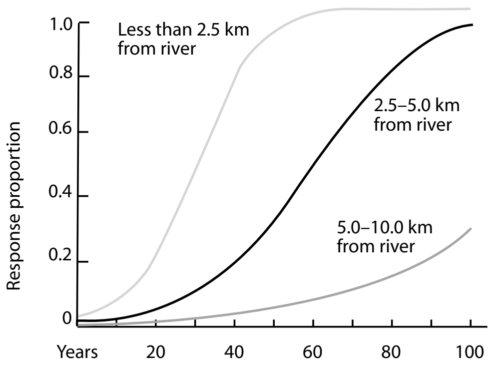

Figure 3. Weighting function for contribution of past recharge to discharge.

Model Calibration

The data required to calibrate the model are extensive. The procedure is presented in detail in Bell and Heaney (2000). Summary data for the irrigation areas are provided in Table 1. Additional information is available from the authors on request. Historical flows and salt loads were obtained from Jolly et al. (1997). Projected salt loads were obtained from the national salinity audit (MDBMC 1999), Barnett et al. (2000) and the Queensland Department of Natural Resources (QDNR 2001). Land use and irrigation data were obtained from a wide range of sources, including ABARE farm survey data and regional water authorities such as Goulburn–Murray Water and SA Water.

Table 1. Summary data for the irrigation areas studied.

Irrigation area	Main irrigated activities	Water allocation (GL)		ET[a] fraction (%)	Recharge fraction[b] (%)	Groundwater salinity (mg/L)
		Murray	Tributary			
Goulburn–Broken	Pasture, cropping, horticulture	320	853	65	50	1,000
Campaspe	Pasture, cropping	207	75	50	60	5,000
NSW Murray	Pasture, cropping	2,464	0	65	75	2,000
Loddon Barr Creek	Pasture, cropping	163	0	65	75	20,000
Murrumbidgee	Pasture, cropping, horticulture	0	2,045	65	80	1,000
Robinvale	Horticulture	31	0	80	100	10,000
Mildura	Horticulture	188	0	80	100	25,000
Lindsay	Horticulture	15	0	80	100	30,000
Lock 3–Lock 2	Horticulture	71	0	80	100	33,000

[a] The percentage of irrigation subject to evaporation and transpiration.

[b] The percentage of excess water, irrigation water and precipitation less evapotranspiration, that enters the groundwater system.

To calculate initial values for the production function parameters in (3), the total rent at full equity accruing to each activity was first calculated as the summation of rent associated with the use of land and other fixed inputs to production and surface and ground water. That is:

$$\text{RentTotal}_j = \text{Rent}L_j + \text{Rent}SW_j + \text{Rent}GW_j + \text{RentOther}_j \quad (6)$$

where

$$\begin{aligned}
\text{Rent}L_j &= L_j(0)p_{\min} \\
\text{Rent}SW_j &= sw_j(0)\tilde{csw} \\
\text{Rent}GW_j &= gw_j(0)\tilde{cgw} \qquad (7) \\
\text{RentOther}_j &= L_j(0)\left(p_j - p_{\min}\right)
\end{aligned}$$

where p_{min} is the net return to land and other fixed capital structures in their marginal use and $\tilde{csw}$ is the opportunity cost of surface water used for irrigation and $\tilde{cgw}$ is the opportunity cost of groundwater used for irrigation in the initial period. Not all regions have groundwater sources suitable for irrigation. The opportunity cost of surface and groundwater used for irrigation is assumed to be \$50/ML for areas with predominantly pasture production and \$200/ML for horticultural areas.

Initial values for the production function coefficients for each activity were then determined as:

$$\begin{aligned}
\alpha_{Lj}(0) &= \frac{\text{Rent}L_j}{\text{RentTotal}_j} \\
\alpha_{swj}(0) &= \frac{\text{Rent}SW_j}{\text{RentTotal}_j} \\
\alpha_{gwj}(0) &= \frac{\text{Rent}GW_j}{\text{RentTotal}_j} \\
A_j &= L_j(0)^{1-\alpha_{Lj}(0)} sw_j(0)^{-\alpha_{swj}(0)} gw_j(0)^{-\alpha_{gwj}(0)}
\end{aligned} \qquad (8)$$

Within a simulation, these coefficients are adjusted from the initial values according to equation (4). The coefficients in equation (4) were derived from estimated yield losses caused by irrigation salinity (MDBC 1999) by equating the decline in average physical product of irrigation water with the yield loss function.

The Murray–Darling Basin Commission has linked its hydrological modelling to estimates based on cost impacts of incremental increases in salinity. Costs downstream of Morgan are imputed as a function of EC changes in salt concentration at Morgan. The analysis considers agricultural, domestic and industrial water uses. Using the cost functions derived in this model, each unit increase in EC at Morgan is imputed to have a downstream cost of \$65,000 (MDBC 1999). This cost is included in the analysis presented here.

Simulation Design

The model was initially used to determine a baseline over a 50-year simulation. The estimated cost of salinity in the baseline scenario is measured as the reduction in economic returns from broadacre and horticultural activities from those that are currently earned. Thus, only costs and/or benefits associated with changes in stream flows, salt concentration and the extent of high watertables from current levels are estimated. Salt loads and salt concentration of the Murray River are predicted to rise over the next 50 years as a result of both the clearance of native vegetation to facilitate dryland agriculture and the increased mobilisation of salt associated with irrigated agriculture. The salt concentration at Morgan, a gauging site on the Murray River below the major irrigation areas, is projected to increase from 590 EC currently to 700 EC by 2050. This increase in salt concentration is expected to result in a decline in agricultural returns of almost \$260 million, in net present value (NPV) terms using a discount rate of 5%, and impose costs to agricultural, urban and industrial water users downstream of Morgan of almost \$60 million at NPV over the 50-year period.

There are many bilateral trades possible within the Murray River system. In the analysis presented here, a subset of bilateral trades between several major irrigation areas is simulated to examine return flow, property rights issues. The trade simulations were selected to allow a comparison of the internal and external costs or benefits of a downstream trade of irrigation water relative to the baseline scenario. Internal (or direct) impacts are derived within the irrigation areas that trade, whereas external (or indirect) impacts are those derived downstream of the areas engaging in trade.

A permanent trade of 20 GL from the source was modelled in each of the simulations. The volume of water available at the trade destination was adjusted to account for conveyance losses. Further, the cap on the volume of water that can be diverted for irrigation is maintained. A decline in irrigation return flows as a result of water being traded from an upstream region will therefore lead to a reduction in water entitlements for downstream users that had previously accessed those flows. However, this reduction can be offset by increases in flows resulting from increased groundwater discharge from dryland areas as an ongoing consequence of land clearing.

Two sets of trade scenarios were simulated. First, a set of trade source experiments simulated trade from several upstream sources to a single downstream destination, the irrigation area within 2.5 km of the Murray River between locks 3 and 2. A second set of scenarios was developed where irrigation water was sourced from one irrigation area, the Goulburn–Broken, and traded to several different downstream destinations. The impact of trade without the cap on diversions for irrigation was also considered to examine the volumetric and qualitative impacts of a reduction in return flows separately. The irrigation areas under consideration are listed in Table 2 in upstream to downstream order and shown in Figure 1. The trade scenarios are listed in Tables 3 and 4. The internal and external costs and benefits associated with trade were then calculated, in NPV terms, over a 50-year period.

Table 2. Major irrigation areas in the southern Murray–Darling Basin.

Irrigation area	Central town
Goulburn–Broken	Shepparton
Campaspe	Echuca
NSW Murray	Deniliquin
Loddon Barr Creek	Kerang
Murrumbidgee	Griffith
Robinvale	Robinvale
Mildura	Mildura
Lindsay	Lindsay
Lock 3–Lock 2	Loxton

Results

Trade source scenarios

Internal benefits from buying water from other regions accrue to irrigators in the Lock 3–2 irrigation region as a result of increased horticultural production (Table 3). As the trade moves water to higher-valued production (horticulture as opposed to pasture and cropping in the source irrigation areas), the benefits to the destination region exceed the costs of the foregone irrigated production in the source regions. For example, the internal cost of foregone agricultural production in the Goulburn–Broken catchment as a result of trade is estimated to be $403/ML. The internal benefit in, for example, the Lock 3–2 region is $2326/ML leading to a total net change of $1923/ML. It should be noted, however, that the capital costs associated with expanding irrigated activity are not included in this analysis. Given current demand and supply conditions and the relatively small volume of water being traded, it is likely that the traded price of water will be close to the observed price of a permanent water entitlement in South Australia. This has been reported to be around $500/ML (Samaranayaka et al. 1998).

Table 3. Net internal and external benefits from trade to Lock 3–2, by source (NPV = net present value).

Source	Net internal benefits $/ML NPV	External benefits $/ML NPV
Goulburn–Broken	1,923	–302
Campaspe	1,967	–318
Loddon Barr Creek	2,156	–107
Murrumbidgee	2,124	–279
NSW Murray	2, 012	–282

The external benefits from trade vary substantially between irrigation areas (Table 3). In each of the simulations presented here, trade results in a negative external benefit as a result of changes in both the volume of water available and water quality. The traded irrigation water is sourced predominantly from pasture production that is generally characterised by low rates of irrigation efficiency. As a result, there is a relatively large reduction in the volume of water available for downstream users directly below the Goulburn–Broken catchment under cap conditions. Further, as recharge rates are higher in the downstream destination regions, surface run-off will be lower, reducing the volume of return flows available downstream of the buyer.

The external impacts of water trade on water quality arise from two sources. First, as the water that would have otherwise been used for irrigation is retained in the river, there is an immediate reduction in salt concentration. Second, the source regions are characterised by relatively low recharge rates and low groundwater salinity, whereas the destination areas have high recharge rates and high groundwater salinity. Trading water from the upland regions reduces the amount of irrigation recharge that, over time, reduces the amount of saline groundwater discharge reaching the Murray River. The combination of reduced saline discharge and dilution flows after the trade lead to reductions in salt concentration in the Murray River between the source and the destination. As a result of the improvement in surface water quality, the productivity of irrigation water increases in the regions between the seller and the buyer.

These findings indicate there may be economic gains from attaching site-specific conditions to the implicit rights to return flows that reflect the cost associated with downstream changes in river salinity. To fully account for the externalities associated with trade between, for example, the Goulburn–Broken and Lock 3–2, the price of a permanent water entitlement would need to reflect the cost incurred by downstream water users. Trade between the Goulburn–Broken and Lock 3–2 has an associated external cost of around \$300/ML as compared with the reported trading price previously cited of around \$500/ML for the region. A charge raising the traded price of water by 60% to around \$800/ML could be imposed to internalise this cost.

Trade destination scenarios

Again, internal benefits are derived from the increase in revenue as a result of the movement of water to higher returning horticultural activities (Table 4). As in the source scenarios, the externalities are a complex interaction of water quantity and quality impacts. The volume of water available downstream of the Goulburn–Broken is reduced under cap conditions as a result of the reduction in return flows. The salt concentration of the Murray River is lower downstream of the source as a result of dilution flows and reduced saline discharge from the upstream irrigation region. Generally, salt concentration downstream of the various destinations increases after trade as the underlying groundwater salinity is higher in the southern irrigations regions and more salt is transported to the river system. However, the impact on stream salinity differs with the agronomic and hydrological characteristics of the destination regions. Reflective of a groundwater salt concentration approaching that of seawater, the negative externality is highest when water is traded to the irrigation area nearest the Murray River in the Lock 3–2 region.

In contrast, trading water to the irrigation area that is more than 5 km from the Murray River in the Lock 3–2 region generates a positive external benefit over a 50-year time period. As the increase in recharge associated with irrigation is further from the river, it takes longer for the groundwater discharge to be transported to the river system consequently delaying the increase in salt concentration.

Table 4. Net internal and external benefits of trade from Goulburn–Broken, by destination (NPV = net present value).

Destination	Net internal benefits (\$/ML NPV)	External benefits (\$/ML NPV)
Robinvale	2,124	–51
Mildura	2 230	–54
Lindsay	1,730	99
Lock 3–2: within 2.5 km of Murray River	1,923	–302
Lock 3–2: more than 5 km from Murray River	1,065	129

An external benefit is also derived when water is traded to the Lindsay region in the Victorian Mallee. The underlying geology of this region is such that groundwater discharge is transported away from the river system. Any increase in recharge is therefore not reflected in an increase in salt concentration in the Murray River. A site-specific condition attached to trade in this scenario could take the form of a subsidy that would reflect the positive effects on water quality of moving irrigation water to this region. In the above scenarios where water quality is improved as a result of trade, subsidies could help offset the increased pumping and capital costs of delivering water to irrigation areas further from the Murray River.

Distributional impacts

The impact of trade on return flows is reasonably complex, as it is both site-specific and dynamic. A reduction in irrigation at the source can have an immediate effect on return flows through reduced irrigation drainage. This would be typical of up-river irrigation areas where there are high water tables and flood irrigation is common. The water quality of surface drainage depends on a number of site-specific factors including the porosity of the soil, the depth of the drains and groundwater salinity levels.

Reduced irrigation at the source will reduce groundwater recharge that will eventually result in a reduction in groundwater discharge to the river system. This can occur relatively quickly in irrigation areas that are near the river and/or where the ground water system is pressurised due to high watertables. In other areas, the effect of decreased recharge on return groundwater flows can be insignificant. Further, as previously noted, the salinity levels of groundwater discharge vary along the Murray River system.

At the destination, the effects of trade are a mirror image of the source impacts in qualitative terms. There can be an increase in both surface drainage and groundwater discharge. However, the magnitude of these effects will depend on the characteristics of the irrigation area. This continuous variation is likely to make addressing distributional issues difficult. As an illustration, downstream trade between the Goulburn–Broken and Mildura is examined. The indirect benefits along successive river reaches are shown in Figure 4.

Trade imposes a small indirect cost on the two reaches directly below the Goulburn–Broken catchment. While the trade results in lower salt concentrations downstream due to the increased outflows from the Goulburn–Broken, this is offset by the impact of

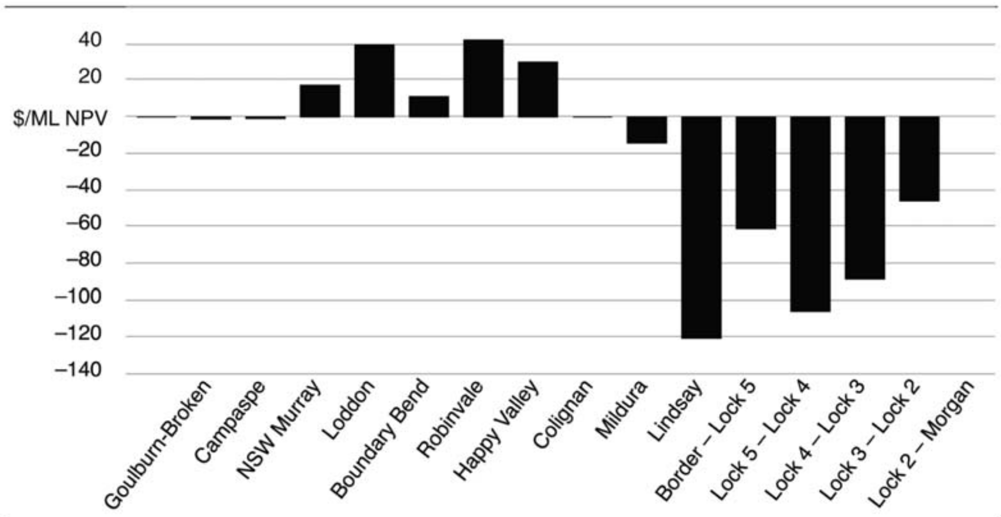

Figure 4. Indirect benefits of trade between Goulburn–Broken and Mildura, by irrigation area.

reduced water availability for irrigation due to the loss of return flows. The distributional impact is reversed further downstream, between the Loddon catchment and Mildura. The effect of reduced salt concentration in the Murray River has a greater impact than the reduction in water available for irrigation. After the trade, the increase in saline return flows from Mildura imposes an indirect cost on downstream users.

The impact of volumetric and qualitative changes

In the simulation experiments presented above, the cap on diversions was maintained resulting in a reduction in allocation for downstream irrigators due to losses in return flows. As a result, external effects on downstream users were a combination of changes in water volume and quality. To examine these effects separately, an additional experiment was conducted where the cap on diversions was removed, allowing downstream users to maintain their allocation despite a reduction in return flows. The simulation was conducted for a trade between the Goulburn–Broken and Mildura and compared with the corresponding simulation where diversions for irrigation were capped. The relative external benefits and costs of downstream changes in salinity concentrations versus water volumes are shown in Figure 5. The total absolute change in costs has been standardised to 100%.

The impacts of volumetric changes are significant only immediately downstream of the Goulburn–Broken. The decline in the importance of the volumetric effects moving downstream is due to the fact that groundwater discharge is increasing over time as a result of the delayed effects of land clearing. The impact of a 20 GL reduction in irrigation in the Goulburn–Broken on the volume of return flows compared with the overall increase in groundwater discharge becomes smaller moving downstream from the Goulburn–Broken. Downstream impacts of salinity dominate the volumetric effects with indirect benefits above Mildura and costs below. The effects below Mildura are predominantly qualitative rather than volumetric for two reasons. First, irrigation efficiency levels are high in Mildura, hence the volume of return flows is low. Second, groundwater discharge from this region is highly saline.

Concluding Remarks

As water becomes a more scarce resource in the Murray–Darling Basin, the need to establish an efficient water market will become increasingly

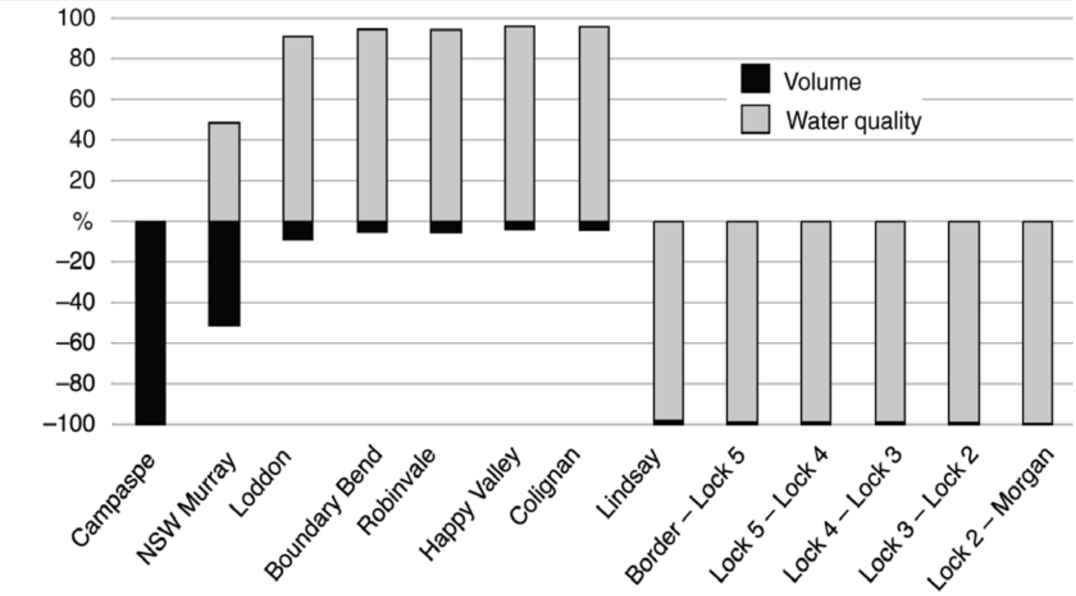

Figure 5. Indirect trade impacts: water quality and volume, Goulburn–Broken to Mildura.

important. At the same time, there is concern about the impact of rising salinity on water quality and river health. However, establishing an institutional framework that will allow efficient water allocation and address the externalities associated with irrigation and salinity remains an elusive policy goal.

Two problems stem from the lack of property rights associated with return flows. Return flows from some irrigation areas represent a substantial proportion of the total water applied. These return flows are partially extracted by downstream users. Furthermore, return flows from some irrigation regions have a major affect on the level of river salinity. Water trade can impact on the pattern of return flows affecting both flow volumes and quality.

Water trade can alter the volume of return flows between the source and the destination. Along the Murray, trade downstream generally reduces the volume of return flows. The impact of reduced return flow volumes on downstream users depends on whether the current cap on diversions is strictly enforced and allocations are reduced. At the same time, trade has the potential to reduce salinity and improve the riverine environment, providing the incentives reflect the full economic impact.

Establishing trading regions and exchange rates that account for the volume and salinity impacts of return flows between regions may be a cost-effective means of improving the allocation of water through trade. The potential gains from such an administrative system may be important in achieving efficient water use in the Murray River system. Using the opportunity costs of the water from the trade sources as a reference price, trade into low impact irrigation areas was estimated to generate salinity benefits in the order of 10–15% of the direct use value of the water traded. Trade into high impact areas was estimated to generate costs of up to 75% of the direct use value of the water traded.

An effective water market in which the arrangements for trade account for salinity impacts due to irrigation may assist in meeting environmental objectives in the Murray River system at least cost. Environmental flows in the Snowy River, for example, may be sourced through the water market. Targeting water purchases for environmental flows to irrigation regions that lead to reductions in saline discharge, thereby improving water quality, may deliver a better policy outcome.

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Developing Policies for Sustainable Irrigation Water Management Using Hydrologic–Economic Modelling Frameworks

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Abstract

Agricultural productivity and environmental concerns due to waterlogging and salinity, coupled with water reforms in irrigation areas, demand hydrologic and economic evaluation of irrigation water management options. This requires a combination of hydrologic, economic and integrated hydrologic–economic tools that can capture and integrate irrigation water management processes at paddock, farm and irrigation area levels. This paper illustrates applications of hydrologic and integrated hydrologic economic models for developing, assessing and implementing irrigation water management policies in Pakistan and Australia. The inputs and outputs of economic significance need to be defined over larger scales than those appropriate for modelling hydrologic responses. A methodology that can capture detailed distributed system response (aquifer response) at the economic unit level is described. The groundwater flow system is initially represented using a finite-difference groundwater model. The crop production and unsaturated zone hydrology are simulated for different soil and land-use types and are incorporated into the hydrologic economic framework as non-linear functions of net recharge, relative yield and irrigation water use using a detailed process model. The hydrological representation of groundwater flow and soil salinisation is incorporated into an economic optimisation model which simulates different policy options such as crop area restrictions and water trading over 15 and 30 year horizons using non-linear optimisation techniques. The integration of hydrology with economics is helping to understand the implications of policy changes, such as the impacts of rice area restriction and water trading on the irrigation system environment and economics under the common pool and social optimum options.

THE productivity of major irrigation areas in the semiarid and arid regions of the world is facing challenges of waterlogging and secondary salinisation of landscapes (Ghassemi et al. 1995). It is estimated that more than 60 million ha or 24% of the all the irrigated land is salinised (World Bank 1992). It is projected in the salinity audit of the Murray–Darling Basin that all irrigation regions within the southern basin will have watertables within 2 m of the surface by 2010 without new interventions (MDBMC 1999). This situation is a combined result of clearing of perennial vegetation and over-irrigation of crops, resulting in seepage losses from fields, supply channels and leakage from storage reservoirs which caused recharge to the watertables. If the groundwater recharge is greater than the groundwater leakage to the deeper aquifers and lateral regional groundwater flows, watertables will start rising. When the watertable is less than 2 m from the soil surface, the root zone becomes restricted and capillary upflows from the watertable start accumulating salts in the root zone causing reduction in crop yields (Kijne et al. 1998). In situations where the quality of shallow groundwater is good, it is possible to tap and re-use the excess groundwater recharge using horizontal tile drains or vertical tube-wells (Keller et al. 1996; Khan and Rushton 1997; Rushton 1999; Seckler 1996) or by adopting appropriate cropping and tree plantations. Remediation of waterlogging and salinisation is difficult if water quality is low in superficial aquifers consisting of slowly permeable materials such as medium and heavy clays. In these

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aquifers, shallow groundwater pumping is possible only in limited locations and re-use or disposal of saline groundwater poses a major problem. Salinity prevention or remediation policies, management decisions and on-ground works to maintain productivity must be supported by appropriate hydrologic–economic tools to achieve the desired results within time and funding constraints.

In addition to the productivity and environmental issues, water-policy reforms in different parts of the world are also posing new challenges to irrigated agriculture. For example, new institutional frameworks are being formulated in Pakistan for management of surface and groundwater resources. In Australia, the Council of Australian Governments (COAG—comprising all the States, Territories and the Commonwealth) articulated a water reform agenda (COAG 1995) aimed at a better process for:

- sharing water between users and the environment;
- trading water between users;
- better defining a water right for users; and
- recovering the real cost of storing and supplying water to users.

Following COAG reforms and a water audit of the Murray–Darling Basin in 1993, the Murray–Darling Basin Ministerial Council (MDBMC) introduced an overall cap on water diversions in 1996, limiting the volume of water to what would have been diverted under 1993–94 levels of development, which is defined as (MDBMC 2000, p. 3):

> … the Cap in any year is the volume of water that would have been used with the infrastructure (pumps, dams, channels, areas developed for irrigation, management rules, etc.) and management rules that existed in 1993/94, assuming similar climatic and hydrological conditions to those experienced in the year in question. Thus, the Cap provides scope for greater water use in certain years and lower use in other years.

The most dramatic impacts of the cap have been an increase in water trading and an increase in the value of water (MacDonald and Young 2000). There is a need to examine the impacts of water trading on the environmental conditions within and downstream of the irrigation areas. This can be done rationally only by understanding hydrologic and economic impacts through appropriate tools which can be used to develop, assess and implement sustainable irrigation water management policies.

Hydrologic Tools for Policy Development

The hydrological tools range from very detailed point-scale crop models such as SWAGMAN Destiny (Meyer et al. 1996) to distributed hydrological models such as MIKE-SHE (DHI 1989). Some studies on modelling the crop, salt and water dynamics in irrigation areas include Ayars and Meek (1994), Ayars et al. (1997), Mudgway et al. (1997), Nathan and Mudgway (1997), Jayatilaka et al. (1998), Khan et al. (1998), Connell et al. (1999) and Khan et al. (2001b). Models describing surface-groundwater interactions at the system level include MODBRANCH, Stream Package for MODFLOW (McDonald and Harbaugh 1988; Christensen et al. 1998) and Mike-SHE (DHI 1989). MODFLOW is a popular hydrologic tool since it offers a simple and widely tested option for simulating surface–groundwater interactions at the required degree of detail (farm, supply channel, irrigation area and catchment scales). Tremendous developments in MODFLOW user interfaces make it easy to operate, maintain and visualise system-scale hydrology using GIS databases. However, a major limitation of the MODFLOW approach is its inability to explicitly consider crop interactions under shallow watertable conditions.

To illustrate policy development through the use of a distributed hydrologic model, a case study in the privatisation of groundwater management in Pakistan is described in this section.

Example of a distributed hydrologic model for policy development

The Government of Pakistan initiated a number of projects (Salinity Control and Reclamation Projects, SCARPS) in the 1960s to address waterlogging and salinity problems. Under these projects, more than 10,000 public tube-wells with 5 to 12 ML/day pumping capacity were installed. The total groundwater pumping from the Indus Basin aquifers increased from 4,000 GL to more than 34,000 GL between 1960 and 1978 from these public tube-wells and other private developments in both fresh and saline groundwater areas. Initially, public tube-wells provided both waterlogging and salinity relief and also supplemented irrigation supplies in fresh groundwater areas. In the Indus Basin aquifers, shallow layers of good quality fresh groundwater often overlie relatively poor quality groundwater. Intensive groundwater pumping from such zones resulted in groundwater mining, deterioration of aquifer quality and exacerbated soil salinity. Within 15 years of their commissioning the number of operating tube-wells started to fall due to deterioration of groundwater quality, poor maintenance and lack of funds. Prior analysis of groundwater flow patterns and the movement of salts, and determining the water quality implications for different locations, rates of pumping and depths of tube-wells could have helped avoid this situation. Recognising these problems, the Government of Pakistan started a program of privatisation of public tube-wells in the fresh groundwater areas while keeping some public tube-wells in the saline groundwater zones. The new privatisation efforts were underpinned by detailed knowledge of the surface and groundwater interactions under changed hydrologic and management scenarios to ensure development of rational surface and groundwater allocation policies and a legal framework for future groundwater development (Punjab Private Sector Groundwater Development Consultants 2000).

To develop and test policies for privatisation of public tube-wells, a project was initiated in the North Rohri area of Sindh, Pakistan in late 1990s (NESPAK et al. 1997). Under this project the 382 SCARP tube-wells (STWs) were replaced with 1800 community/private tube-wells (NESPAK et al. 1997). The pilot project area comprised the Moro and Sakrand units of SCARP North Rohri located between the Indus River on the west and North Rohri Canal in the east, plus a small portion near Sakrand that crosses Rohri canal (Figure 1) between 26°0′ to 26°47′ latitude and 67°55′ to 68°27′ longitude. The gross canal command area is 132,000 ha. This area is irrigated by perennial canals off-taking from Rohri canal and the 382 STWs commissioned in 1978 to be privatised or closed under this project. During the 1990s, the average annual surface water supplies to the area were around 1000 GL while the average public groundwater supplies were around 330 GL. The pilot area comprised a relatively flat alluvial plain laid down over geological time by the River Indus. The general slope of the pilot area is in a south-west direction and ground surface levels vary between 41 and 27 m (135 and 90 feet) above sea level. The groundwater in the project area lies within 2 m of the surface. The average annual rainfall is less than 125 mm and free surface evaporation is around 3000 mm. The geology of the area consists of unconsolidated sediments comprising fine to medium micaceous sands and lenses/bands of silt and silty clay. The general direction of groundwater flow is from north-east to south-west. The groundwater concentrations of salts in project area vary in lateral as well as vertical extents with some visible signs of salinity close to the Rohri canal.

Multi-layered surface–groundwater interaction and solute transport models (MODFLOW and MT3D) were developed to visualise the future aquifer response to changing pumping patterns under different policy options. These flow and solute transport models were used to study the hydrodynamic behaviour of groundwater flow and solute transport on the regional level by simulating four different 20-year pumping scenarios (1997–2017).

Scenario 1: The 1990s rate of groundwater abstraction, i.e. 330 GL/year continues in future. Deep public tube-wells gradually replaced by private tube-wells pumping from shallow aquifer.

Predicted solute concentrations in the shallow aquifer (0–32.5 m) for 2017 are given in Figure 2. Results indicated that, in the shallow aquifer, solute concentrations would increase by more than 1000 mg/L in three zones when compared with the initial conditions in 1997. This change in salinity was a result of upward and lateral movement of higher concentration solutes from deeper aquifers. The areas at risk lie at the tail of the irrigation system and rely mainly on tube-well pumping for irrigation. It was proposed to reduce groundwater pumping in the risk areas by shifting canal supplies from upstream areas to avoid large-scale migration of salts to the surface soils. Subsequent to these studies a new channel was constructed to increase surface water supplies in the lower end of the irrigation system.

Scenario 2: Groundwater abstractions maintained at 330 GL/year and public seepage tube-wells rehabilitated/replaced.

Model predictions for this scenario indicated that three centres of high salinity would be formed and therefore deep pumping from public tube-wells may result in further deterioration of regional groundwater quality. This scenario was supported by the observed salinity trends in the area.

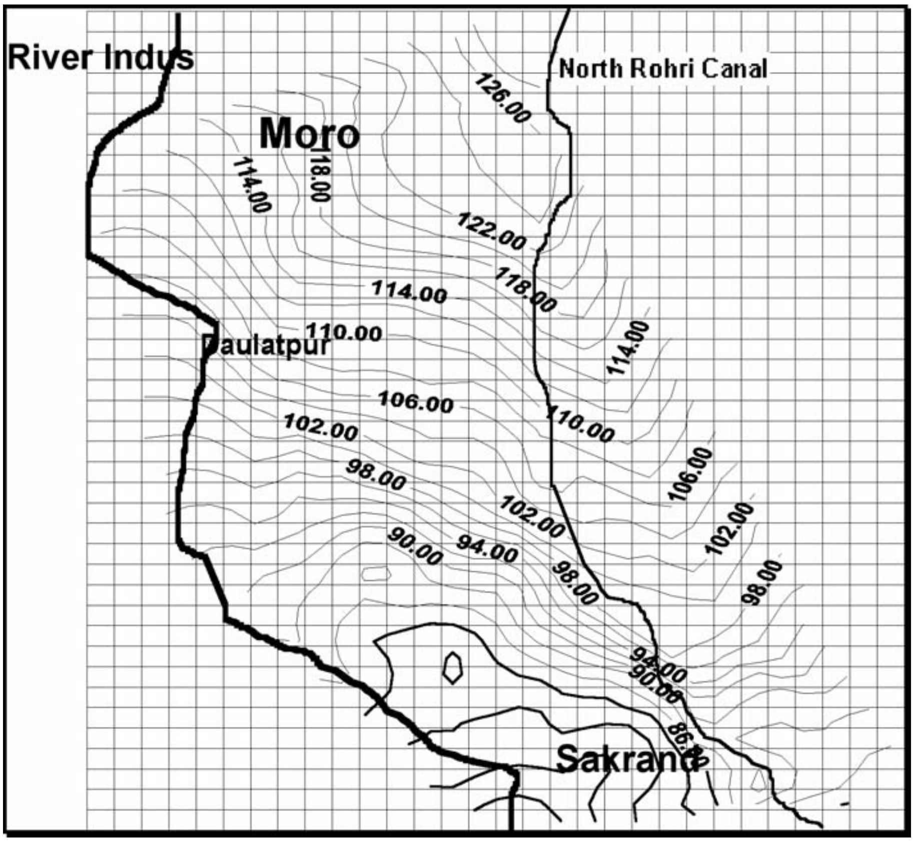

Figure 1. Model area and 1997 watertable contours (feet) in North Rohri, Sindh, Pakistan (cell size is 2 km^2).

Scenario 3: Groundwater abstractions increased to 410 GL/year through private and community tube-wells.

Model results showed similar trends to Scenario 1; i.e. some increase in shallow groundwater salinity in the southern areas whereas there was no change in the northern part of the pilot area.

Scenario 4: Groundwater abstractions maintained at 410 GL/year, seepage interception wells next to the Rohri canal and saline areas rehabilitated/replaced.

Model results indicated that the groundwater could become salinised in the southern half of the project area in both the shallow and deeper aquifers. Therefore, it was proposed that any deeper pumping (deeper than 30 m) must be avoided, particularly in the southern part of the pilot area to avoid upconing of saline groundwater.

The above example illustrates the application of a hydrologic model to explore different water resource management options. Hydrologic techniques have tremendous application to increase understanding of system level hydrology, but in general do not explicitly elucidate social and economic implications of implementing policy options.

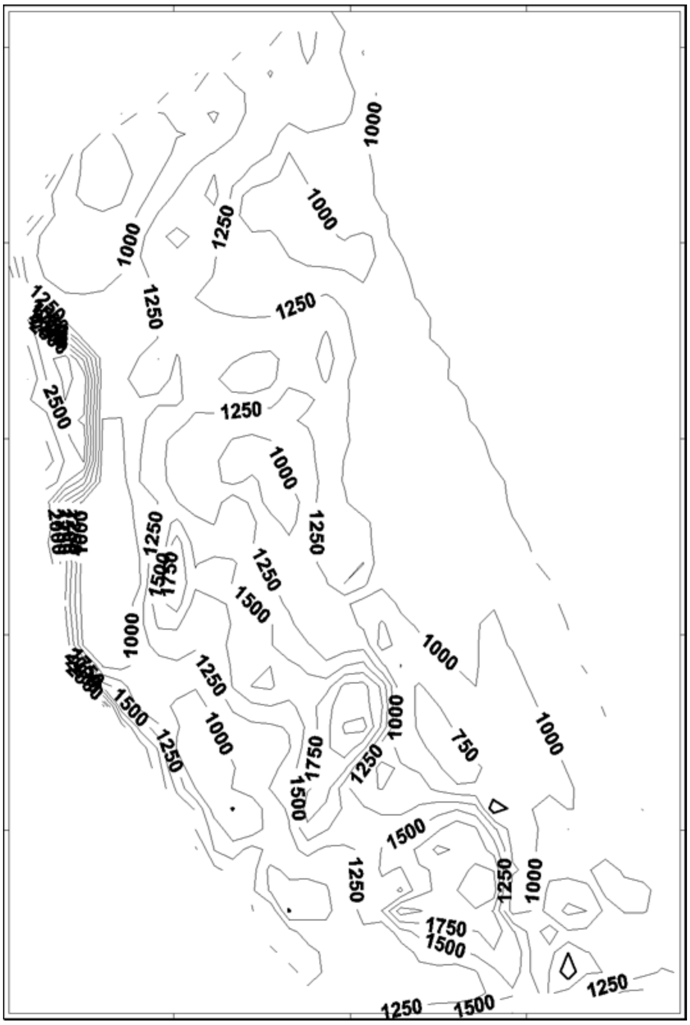

Figure 2. Model results for Scenario 1: groundwater quality (mg/L) (0–32.5 m), year 2017.

Hydrologic–Economic Modelling Frameworks

This section will describe farm-level and irrigation-system-level integrated hydrologic–economic models. Example applications of these techniques in southern New South Wales (NSW), Australia are presented to highlight the relative merits of individual methods.

Farm and subdistrict level approaches

Farm-level bioeconomic optimisation models have been developed to underpin farming policies. Examples of such model include MIDAS (Model of Integrated Dry Land Agriculture Systems) developed by Panell (1997) for dryland agriculture and SWAGMAN (Salt WAter and Groundwater MANagement) Farm for irrigated agriculture initially conceptualised by Prathapar and Madden (1995) and further developed by Khan et al. (2000a).

SWAGMAN Farm can consider different soil types and hydrogeological conditions under different paddocks. This model computes a yearly salt, water and economic balance (Figure 3) for a given farm depending on land use, soil type, changes in soil water content, duration of cropping period, surface run-off, rainfall, evapotranspiration, amount of irrigation, depth to watertable, leakage rates between the shallow and deep aquifers, watertable salinity and leaching fractions. Environmental factors such watertable rise and soil salinity changes in a given year, irrigation allocation, farmer preferences, district policies, groundwater pumping options, interaction with deeper aquifers, soil suitability for different crops and costs and returns are some of the constraints on the environmental sustainability and economic viability of a farm.

Sensitivity analysis of the farm-level model shows that initial soil content, climate variability, water availability and interaction with deeper aquifers are very important factors in the overall environmental sustainability and viability of irrigated farms in southern NSW (Khan et al. 2000a). Khan et al. (2001a) presented applications of this model to assess rice-growing policies in Australia.

To illustrate the capabilities of farm-scale hydrologic–economic models in investigating the hydrologic and economic trade-offs a case study for an irrigated farm in the southern Murray–Darling Basin is presented using SWAGMAN Farm. The total area of the farm is 220 ha and soil types consist of 90 ha of self-mulching Clays (SMC), 90 ha of red brown earths (RBE), 20 ha of transitional red brown earths (TRBE) and 20 ha of sandy soils. The depth to the watertable under the farm is 2.0 m and salinity of the groundwater is 4 dS/m. The total water allocation of the farm is 1400 ML. The leakage rate under the farm is 0.3 ML/ha per year. The salinity of irrigation water is 0.15 dS/m and salinity of rainfall is 0.01 dS/m. The maximum area of any one crop is restricted to 110 ha. The average initial soil water content under the farm is assumed to be 0.25. Average climatic conditions, with annual rainfall of 407 mm and 1779 mm of reference evapotranspiration are assumed. The amounts of water used (ML/ha) by different crops are assumed as 13 for rice, 8 for soybean, 9 for maize, 4 for canola and 2 for barley. The gross margins ($/ha) are assumed as 1,127 for rice, 460 for soybean, 873 for maize, 410 for canola and 278 for barley. The allowable average watertable rise in a year under the farm is varied between 0.1 to 0.5 m and allowable increase of root zone salinity is constrained to 0.1 dS/m to illustrate the economic and environmental trade-offs. The model is run in optimisation mode to maximise total farm gross margin, subject to the watertable and salinity constraints.

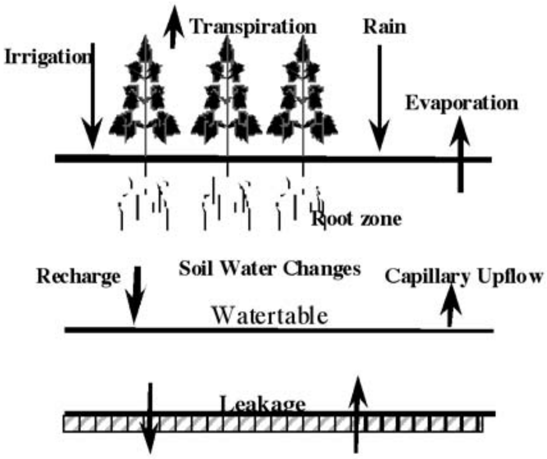

Figure 3. Schematic diagram showing biophysical processes under shallow watertable conditions for the farm-level model, SWAGMAN Farm.

Table 1 shows that, as the watertable constraint is relaxed, more area can be put under higher recharging and more profitable land uses such as rice and maize. Application of the model with the farmer's own irrigation and farm data helps provide insights into economic viability and environmental sustainability.

However, farm-scale models fail to capture system-level hydrologic–economic implications as illustrated by the following example. Figure 4 shows the September 1999 groundwater flow vectors in the shallow aquifer layers in the Murray Irrigation Districts of NSW. Before irrigation the groundwater flow was from east to west but the advent of irrigation introduced channel leakage and on-farm recharge and removed perennial vegetation, and therefore modified the groundwater dynamics. For example, the direction of groundwater flow vectors in the north-eastern part of the irrigation area shows that these areas are affected by groundwater movements from the areas in the south. To develop sustainable irrigation management policies for farms in such groundwater discharge zones, there is a need to consider groundwater dynamics for the entire irrigation area (Khan et al. 2000b). Such situations necessitate capture in the hydrologic and economic analyses underpinning any policy development, of externalities such as groundwater flow emanating from outside the irrigation district, preferential groundwater flow paths, irrigation inefficiencies of the other farms and pumping in the surrounding areas.

System-level distributed hydrologic economic models

The development of regional management policies for shallow saline watertable areas requires integration of spatial hydrogeological dynamics with economics options, to capture and integrate watertable rise, salinity change and economic options at the irrigation-system level. The inputs and outputs of economic significance are defined over larger scales by integrating outputs from the detailed biophysical models. An example of this class of models is the hydrological economic model described by Stubbs (2000), which includes state reduction techniques to define detailed distributed system response (aquifer response) at the economic unit level. The groundwater system is initially represented using a finite-difference groundwater model, and the number of groundwater states is significantly reduced using state balanced truncation techniques commonly used in control engineering. Crop production and the unsaturated zone hydrology are simulated for different soil and land-use types and are incorporated into the hydrologic economic framework as non-linear functions of net recharge, relative yield and irrigation water use using a one-dimensional, finite-element model. The hydrologic representations of groundwater flow and soil salinisation are incorporated into an economic optimisation model which simulates different policy options such as crop area restrictions and water trading over 15 and 30 year periods using nonlinear optimisation techniques. This model is being used with Arc View GIS for data inputs and for the visualisation of results.

Table 1. Impact of relaxing watertable constraint on land use and gross margin.

Allowable watertable rise (m)	Land use (ha)				Gross margin ($)
	Rice	Canola	Barley	Maize	
0.1	53	110	57	–	103,768
0.25	76	110	34	–	119,234
0.5	36	97	20	67	123,307

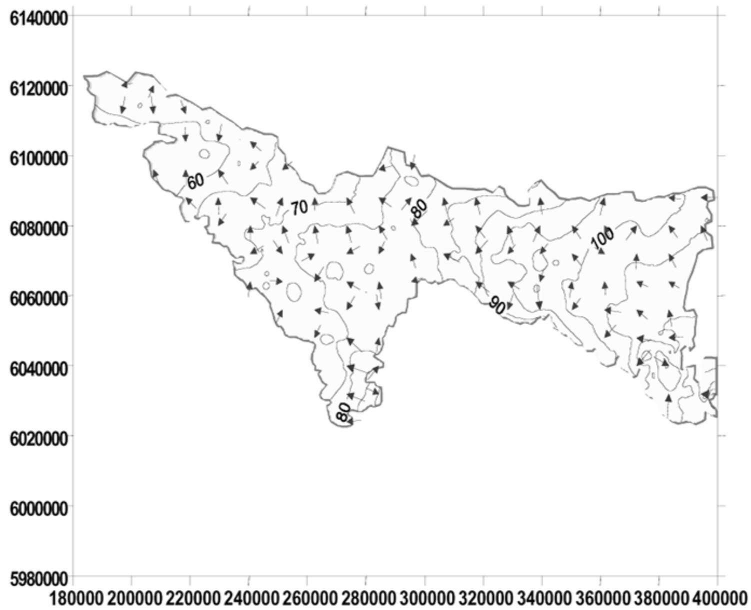

Figure 4. Shallow groundwater flow vectors in the New South Wales Murray Irrigation Districts, September 1999.

Example of a distributed hydrologic–economic model application for policy development

The distributed hydrologic–economic model described above was applied to assess rice-growing policies in the Coleambally Irrigation Area of NSW, Australia. Production functions for recharge, water requirement and crop yield for different land uses as a function of depth of watertable have been developed from experimental data and detailed hydrological simulations using process models such as SWAGMAN Destiny and Hydrus 1D. These production functions capture the climatic variability, changes in irrigation practices, crop salinity response by carrying out several 40-year simulations. An example of a recharge production function for rice, wheat, pasture and fallow land uses is given in Figure 5 which shows negative values as downward recharge to the watertable and positive values as capillary upflow from the watertable.

A detailed groundwater model of the Coleambally Irrigation Area was developed, calibrated, tested and incorporated in the hydrologic economic framework. Incorporation of the surface–groundwater interaction model allows dynamic incorporation of system states in the hydrologic–economic simulations. The irrigation study area was divided into 11 economic units each associated with several surface–groundwater interaction units. The results presented here are indicative only, to illustrate usefulness of this method.

Scenarios such as restrictions or no restrictions on rice area, water trading between the rice areas and from outside the irrigation areas, and groundwater pumping in and around the area, were simulated. Under a given scenario, the model maximises the overall economic returns for the stipulated future years by selecting land uses depending on the system constraints such as water availability, soil suitability, waterlogging and salinity impacts on productivity.

Figure 6 shows time variation in crop areas, recharge and watertable conditions predicted by the

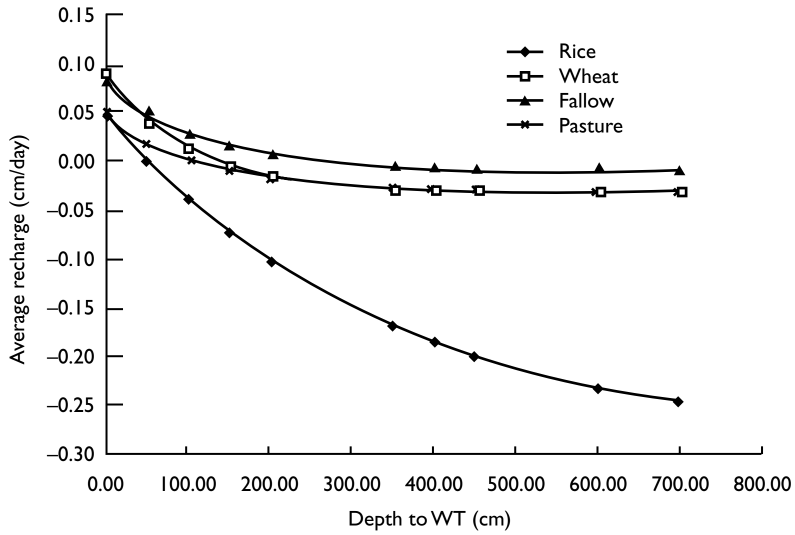

Figure 5. Production functions for recharge on a self-mulching clay soil.

model for economic units 9, 10 and 11 with water markets and no rice area restrictions under a common pool resource (every farm trying to myopically maximise individual returns) scenario. The rice area starts to increase as groundwater levels increase since less water is required to grow the same area of rice.

Figure 7 shows the corresponding net present economic returns for the simulation period. These increase with time as more area can be grown under rice with the same amount of water, as a result of the shallow watertable conditions.

Figure 8 shows the spatial distribution of allowable rice areas under the common pool and water market scenarios. Analysis of different model scenarios indicates that model tends to grow more rice under shallow watertable conditions where the water requirements and downstream impacts are minimum. Allowing water trading between farms tends to shift water to higher value and more water-use efficient land uses under the given market constraints.

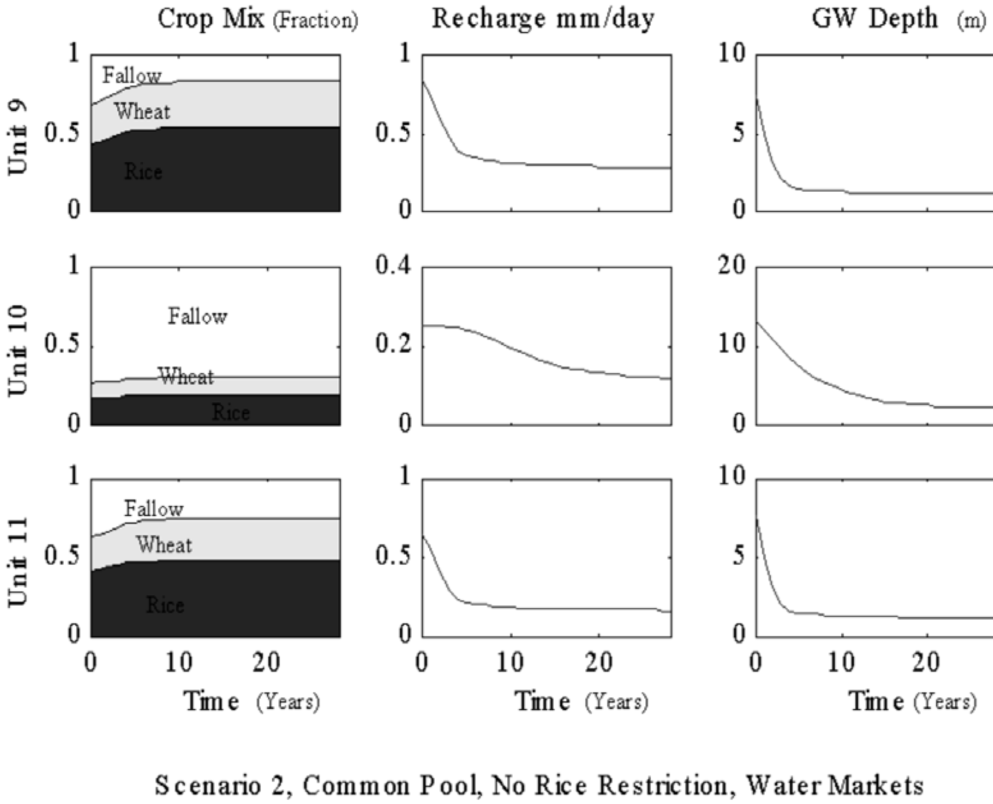

Figure 6. Variation of crop areas, recharge and groundwater depth under a no rice restrictions and water market scenario.

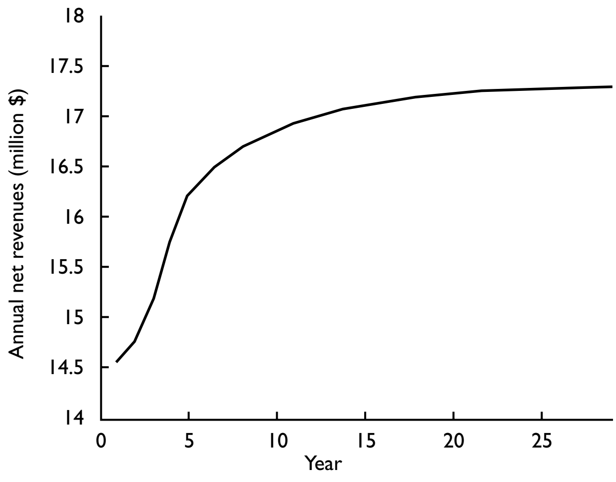

Figure 7. Time-dependent economic returns maximised by the model for no rice restrictions and water markets scenario (scenario 2, common pool, no rice restriction, water markets).

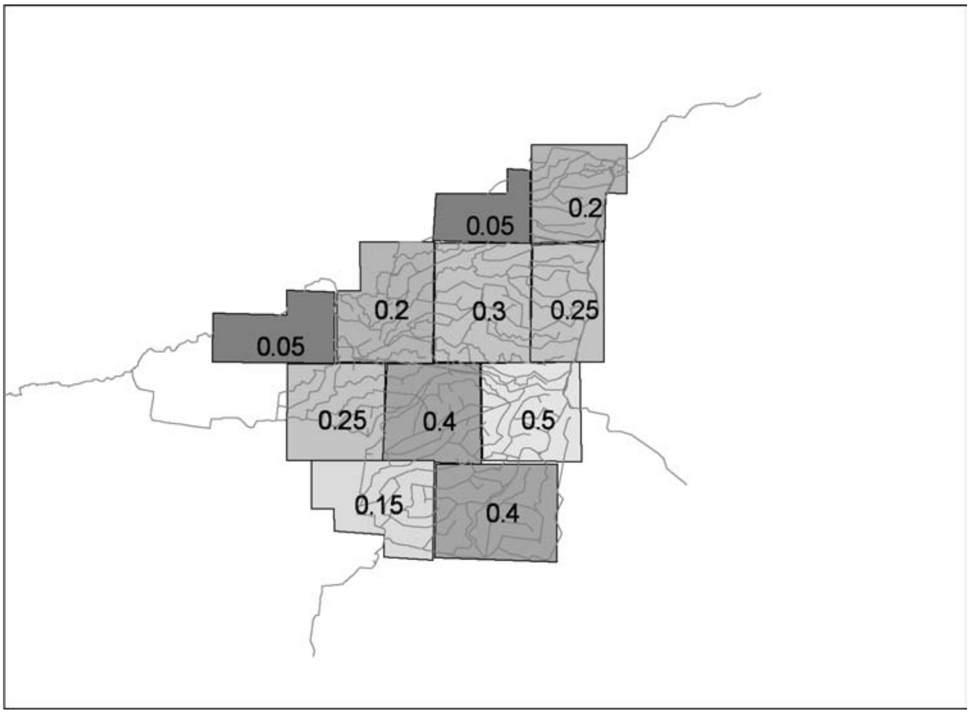

Figure 8. Spatial distribution of optimum rice-growing area fractions for no rice restrictions and water markets scenarios.

Conclusions

The following conclusions are drawn from this work:

- Hydrologic models can be used to assess water policy impacts on the environment, but these methods do not provide insights into the relative economic merit of different policy options.
- Farm-level hydrologic–economic models are useful tools for developing on-farm irrigation management options in situations where off site impacts are minimal.
- In situations where surface–groundwater interactions at the farm level are strongly impacted by the farming practices in other locations and regional groundwater flows caused by externalities, irrigation management policies cannot be developed without considering system-level dynamics.
- The system-scale hydrologic–economic models offer a great potential to assess the relative merits of new water policy options before implementing them in the field.

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Regional Agricultural Implications of Environmental Flows in the Murrumbidgee Valley, Australia

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Abstract

In recent years, there has been both more widespread evidence of the declining health of many of New South Wales' rivers as a result of increased irrigation extractions and increasing community concerns about environmental issues. This has led to a greater focus on the need to re-balance in-stream and consumptive uses of water. In New South Wales, the issue is being approached mainly through the introduction of environmental flow rules across regulated catchments with the nature of such flow rules determined by community based water management committees within an overall framework set by government.

A key issue in deciding on appropriate environmental flow rules is not only the ecological benefits that arise but also the trade-offs associated with re-allocation in terms of reduced production from irrigated agriculture. This paper looks at the nature of this trade-off in the Murrumbidgee catchment. A combination of linear programming and hydrology simulation modelling is used to assess the impacts on agriculture from the implementation of environmental flow rules as developed by the water management committee for the Murrumbidgee Valley.

RIVER regulation and water extractions have contributed to a significant decline in the health of inland rivers across New South Wales (NSW). The Murrumbidgee River in southern NSW is no exception. Median river flows in the Murrumbidgee with current levels of irrigation development are considerably lower than under natural flow conditions, despite additional water supplied by the Snowy Mountains scheme. This has led to the catchment experiencing a wide range of problems including algal blooms, declines in native fish species and an increase in exotic species, poor water quality (including salinity, turbidity, nutrients and pesticides), rising watertables and declines in the health of wetlands.

In response to these types of problems, State governments have been introducing a wide range of water reforms involving the re-balancing of consumptive and environmental uses.[1] In NSW, this has been approached mainly through the introduction of environmental flow policies. In regulated catchments like the Murrumbidgee, water management committees have been given key responsibility for the ongoing development of environmental flow rules to address river health needs, while keeping the impact on water users within 10% of their average annual diversions.

Environmental flows attempt to provide environmental benefits in the form of improvements in water quality and the health of natural ecosystems and aquatic biodiversity. These benefits may be achieved

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1. The recognition of the environment as a legitimate user of water is also a key element of the COAG water reform framework agreed to 1994, and subsequently linked to the broader suite of reforms introduced under National Competition Policy in 1995

through the protection of low flows, providing triggers for fish and bird breeding events, mimicking natural flow variability and restoring a portion of freshes and high flows. The economic benefits attached to these environmental improvements may be significant. However, the trade-offs involved in obtaining environmental benefits may also be large, particularly in States like NSW which historically have taken a less-conservative approach to allocating resources to consumptive uses.

The extent of trade-offs associated with establishing environmental allocations is an important issue in the Murrumbidgee catchment, which has a large irrigation industry dependent upon secure irrigation supplies. The objective of this paper is to evaluate the nature of these trade-offs. The opportunity costs to the agricultural sector from environmental flows are estimated through the application of an economic model of the Murrumbidgee catchment, which draws upon data from a hydrology simulation model to represent environmental flow conditions.

The Murrumbidgee Valley

Location

The Murrumbidgee River Valley is located in southern NSW and covers an area of 84,000 km^2 (Figure 1). The Murrumbidgee River stretches 1,600 km from its source in the Snowy Mountains to the junction with the River Murray down stream from Balranald (DWR 1989). After flowing northwards to Canberra, the Murrumbidgee River then runs west through the main centres of Gundagai, Wagga Wagga, Narrandera, Darlington Point, Hay and Balranald, after which it joins the River Murray. The Murrumbidgee River is regulated by Burrinjuck and Blowering Dams which have capacities of 1026 GL and 1632 GL, respectively.

Irrigated agriculture

Major irrigation areas and districts within the Murrumbidgee Valley include the Yanco and Mirrool Irrigation Areas, collectively known as the Murrumbidgee Irrigation Area (MIA), Benerembah, Tabbita and Wah Wah Irrigation Districts and the Coleambally Irrigation Area (CIA) located on the southern side of the Murrumbidgee River. Irrigation also occurs along the length of Murrumbidgee River through private diverters. The principal production regions, including a number of river pumper zones are outlined in Figure 1. In addition to surface water irrigation, there is significant groundwater irrigation in the lower Murrumbidgee covering the westernmost half of the catchment.

The major irrigated agricultural enterprises in the Murrumbidgee Valley include rice, wheat, oilseeds, citrus, wine grapes, stonefruit, vegetables, annual and perennial pastures supporting livestock enterprises, including prime lambs, wool and beef production. Rice is the most common crop irrigated in the region. The Australian Bureau of Agricultural and Resource Economics (ABARE) estimates that 89% of irrigated broadacre producers in the Murrumbidgee Valley grew rice in 1994–95. The ability of farmers to grow rice is heavily dependent on annual water allocations, which largely determine the profitability of farm businesses.

Irrigated agriculture is an important contributor to the regional economy of the Murrumbidgee Valley. Many of the dominant industries (rice and horticulture) provide inputs into high-value regional processing industries. Hence, any economic impact on irrigated agriculture is likely to have flow-on impacts for regional income and employment. Despite these linkages, it would appear that some farms would be relatively sensitive to any change, either policy or market-based, which eroded current incomes. For example, an ABARE survey in 1996–97 found that the average farm business profit for irrigation farms in the MIA and the CIA was $3,694. More than 30% of these farms recorded business losses (Tran and Samaranayaka 1996).

Reliability of irrigation supplies

Water is made available to irrigators in the Murrumbidgee Valley through a system of individual entitlements and announced allocations. Like other regulated catchments, there are both high security and general security entitlements. High-security irrigation entitlements are generally used to irrigate permanent horticultural plantings and are received in full in all but periods of extreme dryness. General security entitlements, on the other hand, are provided only once all higher security entitlements have been met. They are predominantly used on broadacre agriculture.

In the Murrumbidgee, around 90% of the total irrigation entitlement is in the form of general security entitlements.

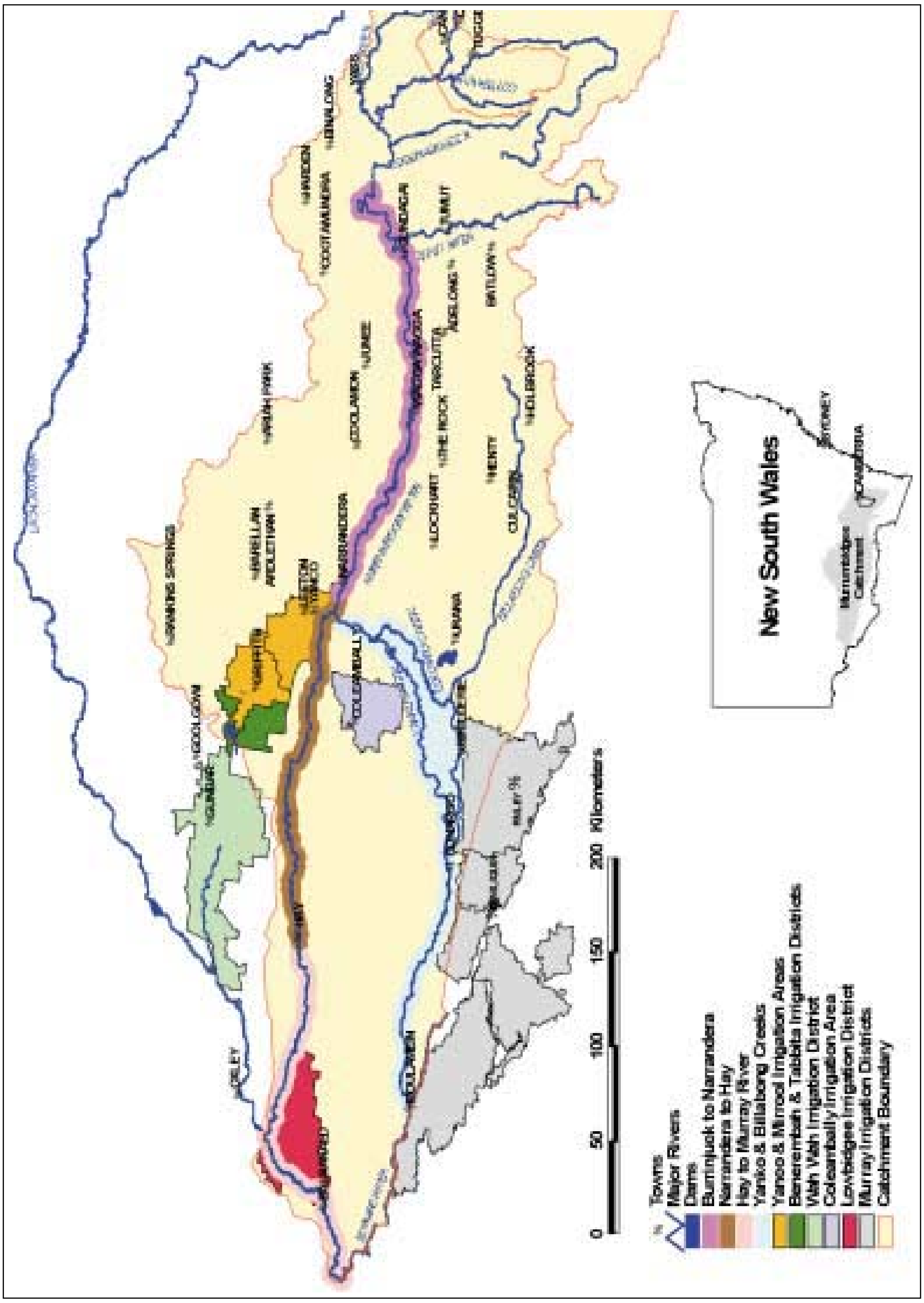

Figure 1. Murrumbidgee catchment showing production regions.

Water availability to general security licence holders is announced as a proportion of entitlement, commonly referred to as an 'allocation'. The announced allocation depends upon the resources currently available in storage and those resources expected to be available during the season. An initial allocation made at the start of the season is updated continuously to reflect rainfall in the catchment. The provision of environmental flows in NSW to date has been taken from general security entitlements and, for this reason, the focus of this section and the remainder of the paper is on general security entitlements and associated broadacre agriculture.

Irrigators in the Murrumbidgee Valley have historically received very reliable irrigation supplies. Simulated hydrology data provided by the Department of Land and Water Conservation (DLWC (Wagga Wagga), unpublished data, based on hydrology modelling of the Murrumbidgee Catchment) show that under base-case conditions, irrigators could expect to receive their full allocations in all but the driest of years (Figure 2). The diversion of rivers in the Snowy Mountains has increased the reliability and flow volumes to the west, providing increased volumes of water for irrigation. The large storage capacity of the Snowy Mountains scheme enables the flow to be controlled, ensuring reliable supplies during periods of low rainfall or drought. On average, the scheme provides around 25% of the flow in the Murrumbidgee River. However, during dry periods, it can provide as much as 60% of the total flow (Snowy Water Inquiry 1998).

The allocation assessment procedure for general security water is structured conservatively so that allocations will not need to be subsequently reduced during an irrigation season unless conditions realised are more severe than the worst recorded drought on record. As the period of record for critical streamflow statistics in most parts of NSW is around 100 years, the minimum-recorded streamflow sequence generally has about a 1 in 100 chance of occurring. That implies there is a 99% chance that the announced allocations will not be reduced.

Not surprisingly, allocations announced at the start of the season have not been revised downwards since the introduction of volumetric allocations in the Murrumbidgee in the early 1980s. Historical allocation announcements actually show that initial alloca-

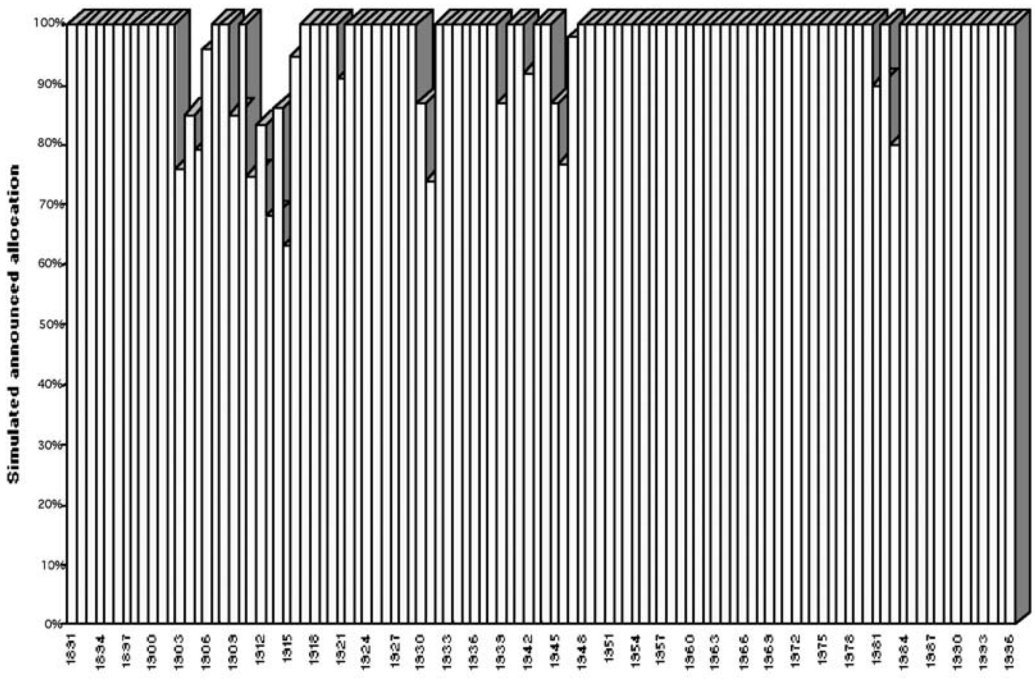

Figure 2. Simulated Murrumbidgee Valley January-announced allocation percentages (1891–1996).

tions were either set at their maximum level (100% or higher) at the start of the irrigation season or set at a lower level and then considerably increased as the season progressed (Figure 3). Looking at those years where less than 120% allocations were announced at the start of the irrigation season (13 of 18 years), the average upward revision in allocation was 39%. There are several reasons for the lower allocation levels since 1995. The Murray–Darling Basin Commission (MDBC) 'cap' which agreed to limit irrigation development at 1993–94 levels and the NSW Government's decision to equally recognise the rights of 'sleeper and dozer' licenses together with the fully active license holders are the main reasons. Drought conditions such as occurred in 1998 also had an impact.

The reliability of irrigation supplies in the Murrumbidgee and the historically conservative nature of allocation announcements by DLWC are likely to have significant effects on the way in which irrigators respond to allocation announcements. The implication is that farmers would be unlikely to base their farm plans solely on announced allocations at the beginning of the season (August and September). This is an important issue for the estimation of the economic impacts arising from environmental flows and is further discussed later in the paper.

Environmental Flows

Environmental issues[2]

River regulation and water extractions have contributed to a significant decline in the health of the Murrumbidgee River. Under natural flow conditions, the median annual flow in the Murrumbidgee at Balranald is about 3.2 ML/year. Model predictions indicate that under 1993–94 levels of irrigation development this has fallen to 645,000 ML/year despite additional water supplied by the Snowy Mountains scheme. The catchment has experienced algal blooms, a significant decline in native fish species and an increase in exotic species, poor water quality (including salinity, turbidity, nutrients and pesticides), rising watertables and declines in the health of wetlands.

River regulation has adversely affected native biota (particularly fish) and wetland ecosystems.

[2] This section draws on material contained in EPA (1996).

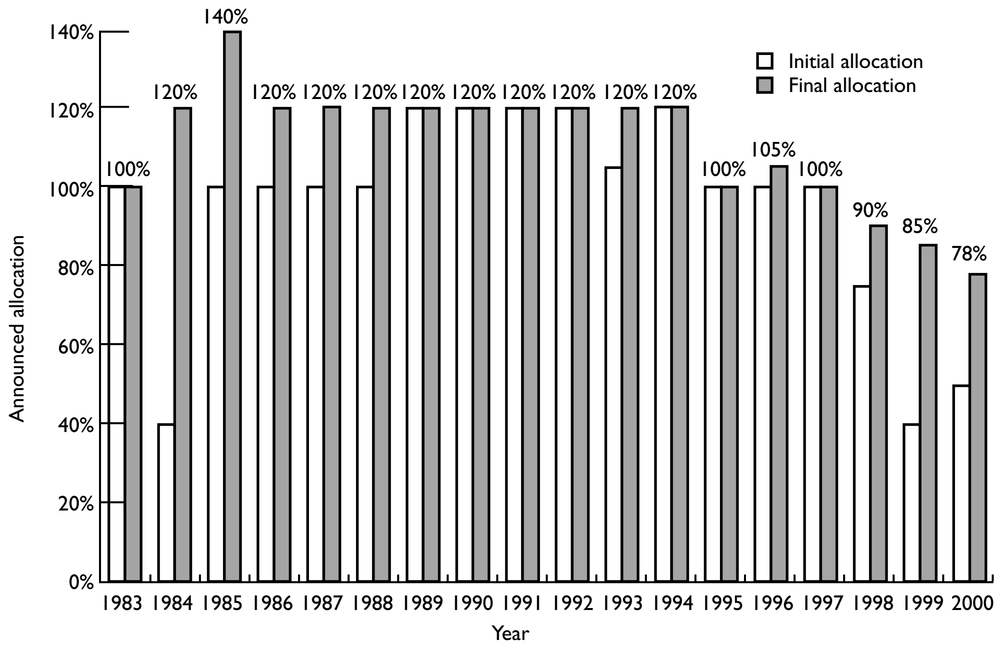

Figure 3. Actual announced allocations—initial and final allocations.

Water released from the bottom of Blowering and Burrinjuck dams is colder than natural flows, particularly in summer. There is evidence that these cold water releases have affected fish in the Murrumbidgee and Tumut Rivers as far down as Narrandera. The Lowbidgee contains one of the largest areas of lignum wetland in the State, and is a regular habitat for waterbirds in eastern Australia. Surveys indicate that the numbers of birds are progressively decreasing.

The Murrumbidgee catchment has lower salinity than other major NSW inland rivers. However, dryland salinity is intensifying. Waterlogging and salinity in irrigation areas also have become major problems, along with the disposal of water draining from irrigated land. These issues are currently being addressed through land and water management plans. Phosphorus concentrations generally increase as one moves downstream and greatly increase during high flows as a result of stream-bank and gully erosion. Algal blooms are commonly reported in summer in the Burrinjuck Dam whilst also being a problem in weir pools in the lower part of the catchment around Hay.

Environmental flow rules

The Murrumbidgee River Management Committee (MRMC) developed a set of flow rules for the 1999–2000 season. These rules were designed to share water between users and the environment to improve river health while providing some level of water security to irrigators. The four individual flow rules described below[3] were implemented as an integrated package, and consequently, should be viewed as simply attributes of the 1999–2000 flow rules.

Rule 1: Dam transparency

Dams on rivers tend to change the quantity and timing of water flow and consequently involve changes to the river environment. 'Dam transparency' refers to ensuring the amount of water flowing into the dam is equal to the amount flowing out during certain periods. In the case of the Murrumbidgee, the rule has been put in place to protect low flows in the river immediately downstream of Burrinjuck and Blowering Dams. The rule states that flows into Burrinjuck at rates of up to 615 ML/day are passed through the dam and into the river. If the inflow is greater than 615 ML, the rate of outflow is limited to 615 ML. For the Blowering Dam, all the inflows up to 560 ML/day are passed through, with an upper limit of 560 ML/day.

Rule 2: End of system flows

This is a flow rule aimed at achieving a certain flow target at the end of a river system. The flow rule in the Murrumbidgee addressing end of system flows is that once irrigation allocations exceed 80%, a target flow of 300 ML/day at Balranald will be maintained during the year. This is calculated as an average daily flow for each month. If the allocation is less than 80%, 200 ML/day at Balranald will be maintained.

Rule 3: Dam translucency

'Dam translucency' means that part of the inflow is allowed to flow through the dam. The translucency rule takes effect from the moment the dam begins to store water. In the Murrumbidgee, this rule has been put in place to ensure that, to some degree, natural flow and variability is restored downstream of Burrinjuck Dam. Both daily inflows and outflows to the dam are examined to determine how to increase the outflows to match and mimic the inflows. Currently, early winter storms are retained in storage, and later storms fill the dam to overflowing. In other words, the dam builds up storage as quickly as possible and is maintained full for the irrigation season.

There are some constraints on the volume of water that can be released under the translucency rule. While Burrinjuck Dam is below a threshold of 30%, up to a maximum of 50% of inflows will be released as translucent water when catchment conditions are 'wet' or 'average'. While Burrinjuck is between 30 and 50% of its capacity there is a maximum of 50% translucency when catchment conditions are 'average'. There is no constraint to releases when conditions are 'dry'.

Rule 4: Environmental contingency allowance/provisional storage

(a) Environmental contingency allowance

An environmental contingency allowance is a quantity of water set aside for future use to meet specific environmental objectives. In the Murrumbidgee under current rules, 25 GL of high security water is set aside each year in Burrinjuck to be used for environmental contingencies that may arise, such as bird breeding, fish migration or blue-green algae outbreaks. Until allocations reach 60%, this 25 GL is included as part of the resource available for allocation. Allocations are not permitted to exceed 60%

3. The description provided draws on DLWC (2000).

until this 'borrowed' water is returned and is again available for environmental use.

(b) Provisional storage

Provisional storage involves the retention of water in storages to meet future irrigation commitments. In the Murrumbidgee, the operation of provisional storage in Burrinjuck and Blowering Dams also helps the river environment by allowing the dams to spill earlier in the following year, providing more natural flows in the river. At the start of the water year, 25 GL is set aside as provisional storage. When the allocation exceeds 80%, the amount of water stored increases linearly from 25 GL at 80% to 200 GL at 100% allocation. The provisional storage becomes available to the environment only in the event of dam spills.

Methodology

Threshold value approach

Resource re-allocation decisions, like whether to re-allocate water from extractive to environmental uses, are commonly assessed in a benefit–cost analysis framework. The economic efficiency of different allocation policies can be assessed by comparing the social benefits and costs associated with each policy. The economic approach of maximising social welfare requires an awareness of relevant benefits and costs, which include environmental values such as clean water or species preservation, that may not be fully or even partially revealed in financial markets.

There are, however, several difficulties associated with adopting the standard benefit–cost analysis framework when considering issues that are likely to yield environmental benefits (many of which may fall in the non-use category) like environmental flows. The major difficulty relates to the appropriate valuation of these types of benefits so that they can be incorporated into a benefit–cost framework. Despite some progress in recent years in the refinement of non-market valuation techniques, there remain significant concerns about both the appropriateness of monetary valuation and the accuracy of the techniques used to evaluate non-use environmental benefits.

General concerns about the appropriateness of monetary valuation relate to the difficulty in identifying some environmental benefits (which may be due to a lack of knowledge of ecological systems), the loss in information that occurs in the process of converting diverse benefits into a single monetary valuation, and the exclusion of values that future generations may place on environmental resources. To overcome some of the conceptual arguments regarding valuation, this study adopts a variation on the standard benefit–cost framework through the use of an 'opportunity cost' or 'threshold value' approach to looking at environmental flows in the Murrumbidgee catchment.

The threshold value approach avoids the need to directly place monetary values on environmental goods. The approach is based upon estimating the 'opportunity costs' that would be the consequence of a particular resource decision. The opportunity costs are then compared with the unquantified environmental outcomes that are expected from the proposal. This approach has been used in a wide range of environmental studies overseas and in Australia, including studies undertaken by the Resource Assessment Commission, ABARE and the Australian National University.[4]

In benefit–cost terms, the opportunity cost approach identifies the size of environmental benefits that would be necessary to equate to the present value of the stream of opportunity costs associated with the proposal (i.e. in order to achieve a benefit–cost ratio of one). This provides information to the decision-maker (i.e. MRMC) to consider the economic trade-offs associated with water management changes. For example, if the potential unquantified benefits (i.e. environmental benefits from increased river flows) from the proposal are considered by decision-makers to exceed the quantified opportunity costs (i.e. regional agricultural costs), the proposal should proceed.

Overview of modelling system

Earlier in this paper, we outlined features of the process used in determining seasonal irrigation allocations. It was noted that allocations change significantly over the course of a year and how irrigators respond to these announcements may be important in assessing policies affecting water availability. Environmental flow policies not only lower overall water

4. See Streeting and Hamilton (1991), Young and Mues (1993) and Saddler et al. (1980).

availability but also influence the magnitude of allocation adjustments occurring throughout a season. This highlights a need for an approach to have some capacity to consider tactical responses to changes in water availability.

A combination of economic and hydrological simulation modelling is used to assess the impacts on agriculture from the implementation of environmental flows (Figure 4). Agricultural impacts are determined by quantifying the difference in agricultural returns between the base-case scenario (water availability without environmental flows) and environmental flow scenarios (various reduced water availabilities) for each year of the simulation period.

The economic modelling system allows for farmers to make both strategic and tactical management decisions by adopting a two-stage solution process reflecting conditions at the start and at the end of the irrigation season. The base-case and environmental flow scenarios are represented in hydrological terms as a set of initial and final allocations over a simulation period of 106 years. Other key inputs in the modelling system include historical climatic data which drive seasonal irrigation demand. The components of the modelling system are described in detail the following sections.

Economic model

The economic modelling is undertaken in two stages as outlined below.

Stage 1. Strategic decision economic model

The first stage economic model accounts for strategic decision-making, and determines the optimal farm plan for each zone, based upon the initial announced allocation, as provided by DLWC's hydrology model, plus some expected level of allocation adjustment. The first-stage strategic decision-making model is solved using the expected allocation and expected rainfall values to derive the optimal farm plan for the irrigation season in each production zone. The farm plan is that which maximises regional agricultural returns (gross margins) by optimising levels and mixes of crops, pastures and livestock activities subject to resource constraints. Expected irrigation water demand is determined by crop evapotranspiration less expected monthly rainfall for the irrigation season. The 25^{th} percentile for monthly rainfall, rather than the mean, is used for expected rainfall to reflect assumed risk-averse decision-making behaviour by irrigators.

Stage 2. Tactical decision economic model

The second-stage economic model represents the tactical decision-making by farmers, and determines the adjustments to the farm plan when an outcome of more or less water than planned for is realised. The optimal farm plan derived in the strategic economic model for each year is transferred to a tactical decision-making model, which is solved using actual monthly rainfall and end-of-season announced allocation. This process allows for a range of possible tactical responses by Murrumbidgee Valley irrigators if monthly rainfall and allocation availability differ to the expected values. The following tactical responses are included:

- if actual seasonal rainfall exceeds expected rainfall, total seasonal utilisation of irrigation water will be less than available allocation. No tactical responses will occur, but regional gross margin will be higher because of variable cost savings (reduced water use);
- if actual allocation availability exceeds the expected allocation the same result occurs as above (surplus water);
- if actual seasonal rainfall is less than expected rainfall then the demand for irrigation water will increase. If irrigation water is constraining, then a number of tactical responses will be made. For example, conversion of irrigated crops and pastures to dryland, abandonment of crops, and fodder purchases for livestock; and
- if actual allocation availability is less than the expected allocation the same result occurs as above (on farm tactical responses).

The economic model used in this study is based on linear programming (LP) techniques. LP provides a large degree of flexibility in looking at problems, and has been applied to a wide range of resource management problems to determine the most economically efficient allocation of resources given a range of alternatives and constraints. It is particularly valuable in rapidly assessing potential changes in water resource availability and has been extensively used in regional planning (land and water management plans) and water related research (assessment of the impacts of changes in water availability, water pricing and trading) in NSW and Australia. More recently, linear programming has been combined with hydrology simulation modelling to evaluate the impacts of changes in resource availability through time.[5]

While offering a number of advantages, there is a range of well-documented deficiencies of linear programming methods (see Hardaker 1971; Dent et al. 1986), including:

- the assumption of linearity;
- perfect divisibility; and
- an objective function which maximises gross margin (in this case) where other objectives such as the minimisation of risk and accumulation of wealth could be equally applicable.

However, many of the deficiencies usually raised in respect to LP are raised in the context of very simple LP models and can be either overcome or minimised with a little thought. For example, goals other than profit maximisation can be incorporated within the framework in the form of constraints. Linearity issues can sometimes be dealt with by disaggregating production responses. Divisibility issues sometimes present problems at a farm scale but are not a concern at more aggregated levels, such as regional modelling.

The advantages of LP in this application, and to many others no doubt, arise from the need to specify an objective function. The function makes it clear as to what goal alternative options are being evaluated against and allows the analysis to be undertaken in a transparent and consistent method. In doing so, the results of these evaluations can often provide useful insights into the problem under consideration which may not have been readily apparent in the absence of the model.

Using the LP approach, changes in water availability arising from environmental flows directly impact on the area of irrigated enterprise and resulting returns. It is assumed that farmers respond to reductions in water availability by changing their crop/livestock mix to make the best use of the available water and/or convert irrigated production to dryland. In the absence of sufficient water, crops that cannot be grown without irrigation are replaced with a dryland enterprise to offset some of the income loss.

NSW Agriculture's existing economic model of irrigated broadacre agriculture in the Murrumbidgee

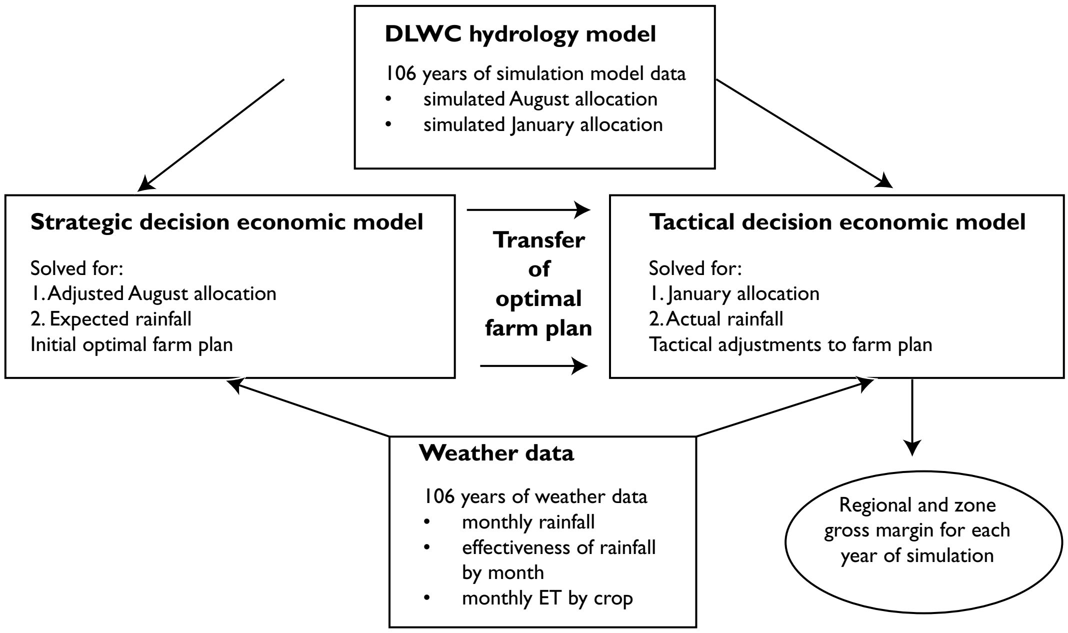

Figure 4. Structure of the modelling system.

5. See ABARE (1999) and NSW Agriculture (1996a).

Valley has been revised to analyse economic impacts of flow rules at a disaggregated level across the catchment. The disaggregated model takes into account variations in crop yields, variable costs, crop water requirements, irrigation efficiencies and water use for each of the production zones. These types of variations significantly affect the profitability of irrigated agriculture and hence influence the magnitude of impacts associated with environmental flow rules.

The economic models developed for each of the zones in the Murrumbidgee maximise zonal gross margin (M) according to the objective:

$$M = \sum_{j=1}^{n} \left(c_j - a_{ij} \cdot x_j \cdot p_i \right), \qquad (j = 1, \ldots\ldots\ldots n)$$

where:

c_j denotes all the revenue from activities j;

x_j is the magnitude of activity j;

a_{ij} is the amount of resource i used per unit of activity j;

p_i is the cost of resource i; and

n is the number of j activities.

subject to:

$$\sum_{j=1}^{n} \left(a_{ij} \cdot x_j \leq a_i \right), \qquad (i = 1, \ldots\ldots\ldots, m)$$

The same mathematical notation could be used to denote both strategic and tactical economic models. An additional feature in the tactical model is that the magnitude of irrigation activities is constrained to the levels found in the strategic model. Within these new constraint levels the tactical economic model allows conversion of some irrigation activities to dryland. The specifications of the model, including the agricultural activities, constraints and data sources, are outlined in Appendix 1.

Hydrology model

Hydrology simulation information from DLWC's monthly hydrology model is used to represent the allocations that irrigators expect to receive under different environmental flow scenarios through time. The DLWC hydrology model (DLWC 1997) simulates the operation of the Murrumbidgee system by determining start- and end-of-season irrigation allocations, calculating the monthly announced allocation percentages and total allocation diversions for each year of a 106-year simulation period from 1891 to 1996.

The hydrology model is set to represent, as closely as possible, all the factors affecting water use as they were in 1993–94. These factors include dams and water storages then in place, the water allocation rules, amount of land being irrigated, the year by year planting decisions made by farmers etc. The model is simulated with the actual rainfall, evaporation and water inflow for the period 1891 to 1996 to obtain the simulated hydrology output.

Hydrological data are used as a starting basis to represent the allocations that irrigators would receive under environmental flow scenarios through time. The conservative nature of DLWC allocation announcements (discussed earlier) suggest some likelihood of irrigators upwardly revising such announcements for planning purposes. The extent of such revisions ultimately depends on the irrigators' attitudes to risk, which are likely to be individual specific. Without knowledge of these individual responses, two alternative responses were assessed.

The first response was developed by examining some of the characteristics of the hydrology data. According to data, allocations increase from the initial allocation (August) to the final allocation (January) under the base case situation by an average of 29%.[6] This average increase was used in the analysis by assuming that irrigators would upwardly revise DLWC's August announced allocation by 29%[7] (with and without environmental flows) subject to a maximum allocation of 100% for each year of the simulation period. This option implies that irrigators are well informed about the usual increase in allocation announcements and that they base their crop planting decisions on higher water availability than that is actually announced at the start of the irrigation season.[8]

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6. Years that reported the maximum allocation of 100% in August were excluded as this reflects the maximum volume of water which could be made available to irrigators under current policy.

7. A revision of 29% is taken as a proportional increase in the announced allocation. Hence, under this assumption an announced allocation in August of 65% would translate to irrigators' planning on receiving a 84% allocation (65% × 1.29).

8. According to historical announced allocations, the average increase in allocations between the start and the end of the irrigation season between 1983 and 2000 amounted to 39% (excluding years where 120% allocations were announced).

The second response assumed that irrigators would upwardly revise DLWC's August announced allocation by just 15%, subject to a maximum allocation ceiling of 100%. The allocation revision was based on the advice of irrigator representatives on the MRMC who believed that an allocation revision of 29% was well beyond what most irrigators would normally base their crop planting decisions on.

Results

Hydrology results

Figure 5 gives a summary of DLWC hydrology data in the form of cumulative distribution functions (CDFs). The CDFs provide an indication of the probability of receiving a particular announced allocation under the base-case and the environmental-flow scenarios. For example, when looking at final allocations in January, we see that under base conditions irrigators have less than a 20% chance of receiving less than 100% of their entitlement. Under environmental flows, irrigators have around a 60% chance of receiving a final entitlement less than 100%.

Figure 5 also provides some perspective on the extent to which allocations change over the season (between August and January). Seasonal allocations increase significantly under both base case and environmental flows, but the magnitude of the increase in allocation over the season is much larger under environmental flow rules than the base case. This can be seen in the gap between the CDFs representing initial and final allocations in both scenarios.

Economic results response 1—a 29% allocation revision

The agricultural impacts of environmental flow rules under response 1 are estimated across the Murrumbidgee Valley in terms of reductions in agricultural returns. The average results of the 106-year simulation analysis for each zone are summarised in Table 1.

Introduction of environmental flow rules reduced the mean agricultural returns in the Murrumbidgee Valley by \$2.81 million, a 1.9% decline. The impact of environmental flow rules varied across different zones in the valley. The highest impact in nominal terms of \$0.99 million is estimated in the MIA,

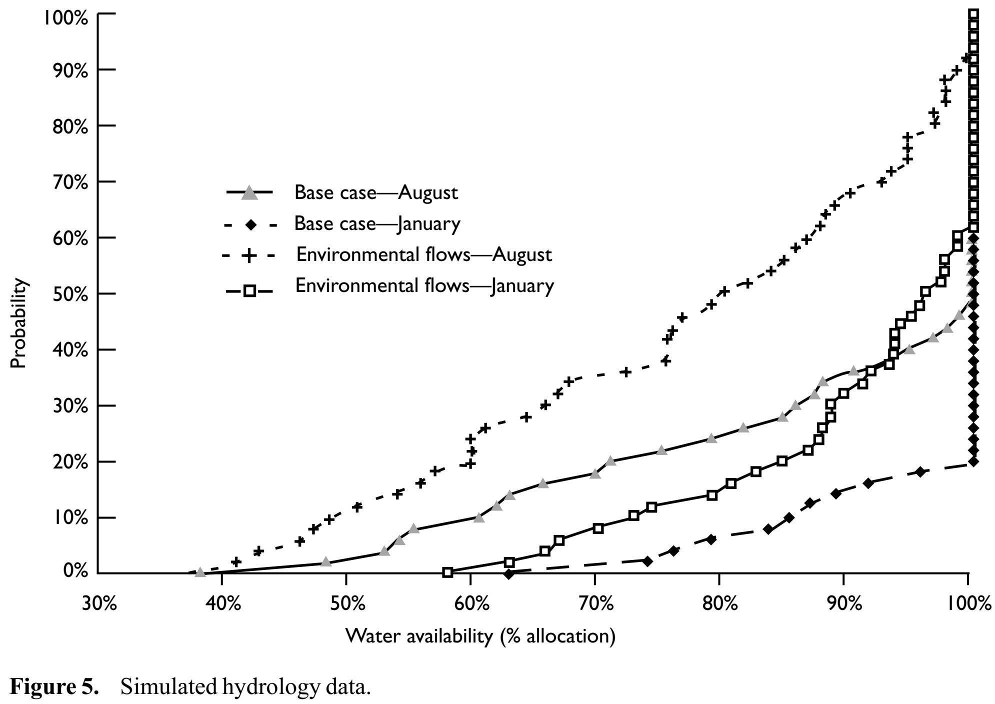

Figure 5. Simulated hydrology data.

around a 1.9% fall for that zone. The impact in the Coleambally Irrigation Area (CIA) is $0.88 million, but as the gross margin for this zone is around half of that of MIA, the fall stood at a high 3.5%. The first three river pumper zones ranging from Burrinjuck to the Murray River did not show much impact, but the Yanco and Billabong Creeks indicated a $0.25 million decrease which is around 2.9% of its total.

Further analysis was undertaken to determine whether the agricultural impacts of environmental flows were statistically significant. The analysis found that the total regional impacts of environmental flows in the Murrumbidgee Valley across the 106-year simulation period were statistically significant at the 5% level (t-stat = 2.58, critical t value = 1.65).

The non-normal distribution of allocation announcements under both the base case and environmental flows suggests that a simple comparison of results on the basis of mean and standard deviations may lead to false conclusions. A test for stochastic dominance was undertaken on the resulting distributions of the base-case and environmental-flow scenarios. The concepts of first, second and third degree stochastic dominance progressively use more restrictive behavioural assumptions to identify stochastically inefficient or dominated distributions (Anderson et al. 1977). The cumulative distribution functions (CDFs) for the base case and environmental flows are plotted in Figure 6.

Results indicate that the base case dominated environmental flow rules in the order of first-degree stochastic dominance, with its CDF lying entirely to the right of the environmental flows CDF. First-degree stochastic dominance is based on Bernoulli's principle that decision-makers prefer more to less of a consequence such as profit (Anderson et al. 1977). In this context, the results indicate that agricultural returns in the Murrumbidgee Valley are lower under situations of environmental flows than the base case across the entire probability range. Rational decision-makers will always prefer the base case to environmental flows under the behavioural assumption that they prefer more income to less.

Table 1. Summary of agricultural impacts.

Planning on August announced allocation plus 29% more, subject to a maximum allocation of 100%.						
Zone	**Base case – average January allocation 96.74%**		**Environmental flows – average January allocation 91.71%**		**Impact of environmental flows**	
	Mean ($m)	**SD ($m)**	**Mean ($m)**	**SD ($m)**	**Mean ($m)**	**% change**
MIA	50.94	2.96	49.95	3.63	–0.99	–1.9
Ben	21.71	1.19	21.17	1.61	–0.53	–2.5
Wah	4.86	0.22	4.76	0.30	–0.10	–2.1
CIA	24.77	1.96	23.89	2.63	–0.88	–3.5
Zone 5	0.67	0.01	0.67	0.01	0	0
Zone 6	14.80	0.21	14.73	0.31	–0.07	–0.5
Zone 7	18.50	0.05	18.50	0.05	0	0
Zone 8	8.48	0.56	8.23	0.75	–0.25	–2.9
Total region	144.72	6.75	141.91	8.96	–2.81	–1.9

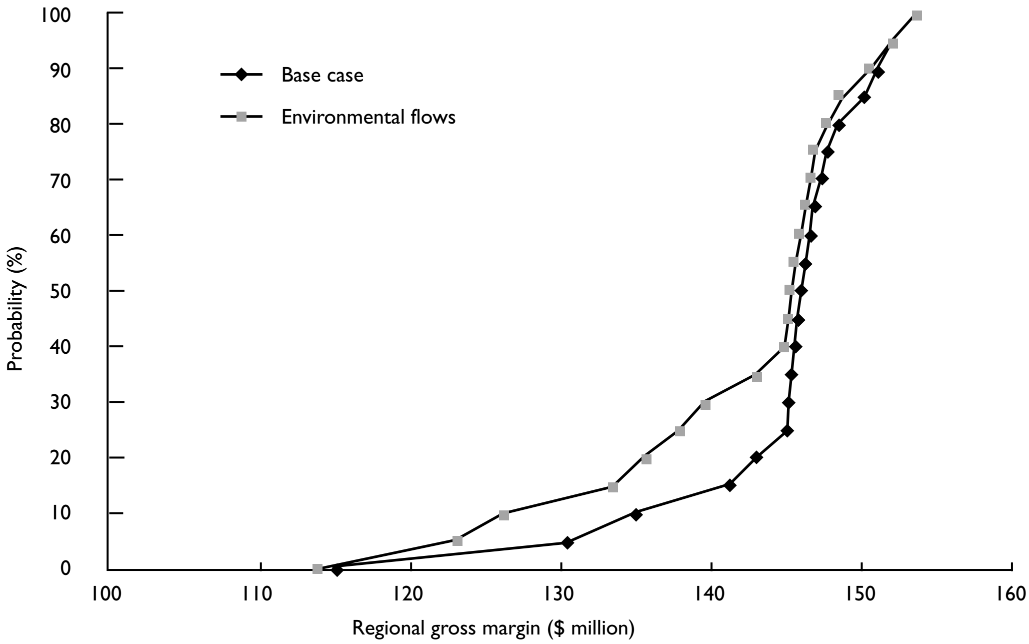

Figure 6. Cumulative distribution of total regional gross margin under response 1.

Response 2 — a 15% allocation revision

The agricultural impacts of environmental flow rules under response 2 are estimated across the Murrumbidgee Valley in terms of reductions in agricultural returns. The average results of the 106-year simulation analysis for each zone are summarised in Table 2.

The reduction in mean agricultural returns due to environmental flows was estimated to be $4.1 million (2.9%) under a 15% allocation revision compared to $2.81 million (1.9%) under a 29% allocation revision. Again, the impact of environmental flow rules varied across different zones in the Murrumbidgee Valley. The highest impact in nominal terms of $1.49 million is estimated in the MIA, around a 3.0% decrease for that zone. The impact in the Coleambally Irrigation Area (CIA) was $1.27 million, equating to a 5.2% reduction in the gross margin for this zone. The statistical significance of the results (at the 5% level) were again confirmed by testing the 106 years of simulation results (t-stat = 3.14, critical t value = 1.65). Agricultural returns under situations of environmental flows were found to be consistently lower than without such flows.

Table 2. Results of sensitivity analysis—summary of agricultural impacts.

Planning on August announced allocation plus 15% more, subject to a maximum allocation of 100%.						
Zone	**Base case – average January allocation 96.74%**		**Environmental flows – average January allocation 91.71%**		**Impact of environmental flows**	
	Mean ($m)	**SD ($m)**	**Mean ($m)**	**SD ($m)**	**Mean ($m)**	**% change**
MIA	50.45	3.46	48.96	4.16	–1.49	–3.0%
Ben	21.46	1.48	20.72	1.89	–0.75	–3.5%
Wah	4.82	0.27	4.68	0.34	–0.13	–2.8%
CIA	24.37	2.46	23.11	3.08	–1.27	–5.2%
Zone 5	0.67	0.02	0.67	0.02	0	0%
Zone 6	14.76	0.28	14.65	0.43	–0.11	–0.7%
Zone 7	18.50	0.05	18.50	0.05	0	0%
Zone 8	8.37	0.69	8.01	0.88	–0.36	–4.2%
Total region	143.40	8.35	139.30	10.54	–4.10	–2.9%

The non-normal nature of allocation distributions and the effect that this can have on the results of the economic model were evaluated in terms of stochastic dominance. The two scenarios under the 15% allocation revision are reported as CDFs in Figure 7. The results indicate that the base case again dominated environmental flow rules in terms of first-degree stochastic dominance, with its CDF lying entirely to the right of the environmental flows CDF. In this context, the results indicate that agricultural returns in the Murrumbidgee Valley are lower under situations of environmental flows than the base case across the entire probability range.

The results for response 2 indicate that the size of the allocation adjustment influences the relative impact of environmental flow rules. The sensitivity of impacts to modelled allocation revisions relates to the hydrology simulation data. As discussed earlier, in 'Hydrology results', under environmental flows the magnitude of the increase in allocation over the season is much larger than the base case. More conservative allocation revisions reduce agricultural returns because water actually made available in the season is not utilised by the irrigation sector and the frequency of this under-utilisation increases using the hydrology data for environmental flows.

The results indicate that a more conservative allocation adjustment reduces agricultural returns for both the base case and environmental flow rules. This is because a 15% allocation revision is significantly below the average revision indicated by hydrology simulation data for both the base case and environmental flow rules. The implication of this result is that agricultural returns are actually higher when irrigators base their farm plans around historical allocation adjustments or averages indicated by hydrology simulation data, rather than modest revisions like 15%. This is because the benefits derived from planning on higher allocations outweigh the losses involved in years when higher allocations fail to eventuate.

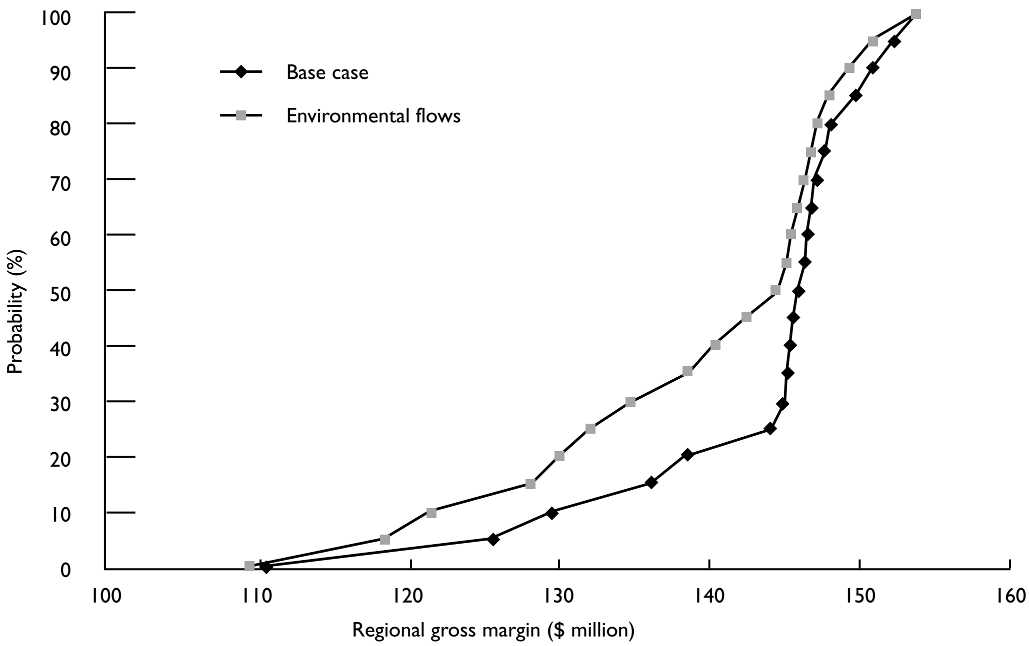

Figure 7. Cumulative distribution of total regional gross margin under response 2.

Summary

The results of the paper shed some light on the agricultural trade-offs associated with the implementation of environmental flows in the Murrumbidgee catchment. In benefit–cost terms, these costs provide an indication of the level of environmental benefits (threshold value) which would need to be obtained from the environmental flows if such a move could be supported on economic grounds. The results provide a starting point for decision-makers to weigh up whether the environmental benefits (often identified and measured in physical terms, but which cannot be easily measured in monetary terms) from the proposal are considered to exceed the quantified opportunity costs.

The impact of environmental flow rules was found to be sensitive to the extent of allocation revisions made by irrigators. It was clearly shown that more-conservative allocation revisions (a 15 rather than a 29% allocation revision) lower agricultural returns because water actually made available in the season is not utilised by the irrigation sector. The frequency of this under-utilisation increases using the hydrology data for environmental flows. This problem may be of greater significance if environmental-flow policies prompt irrigators to act even more conservatively in farm planning decisions.

The results of the study suggest that there is an important issue regarding strategic and tactical decision-making for water allocation planning. There would appear to be insufficient tactical options available to irrigators to make up for an initial conservative farm plan. This suggests that water-management agencies should consider whether the information they currently provide to irrigators is adequate in the current environment. Additional information may assist irrigators to develop more appropriate farm plans, which would help in reducing agricultural trade-offs associated with environmental flows. The results of this analysis suggest that the value of improved information on allocation availability may be quite high and highlights an area for further economic research.

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Appendix 1. Murrumbidgee Catchment—Agricultural Data

Agricultural returns are based on crop and livestock gross margins, defined as gross agricultural income less the variable costs incurred in production aggregated across the relevant production zone. This is an indication of the profitability of agriculture in the production zone and can be used for estimating the impact on the agricultural sector of reduced water availability.

Some of the key data inputs into the economic model are discussed below:

- Commodity prices—crop and livestock commodity prices are a key input and are based on average prices received over the last three years.
- Enterprise areas—outputs are validated against a variety of information sources including departmental publications, research and extension staff within NSW Agriculture, information collected during catchment based planning initiatives (e.g. land and water management planning), Australian Bureau of Statistics and DLWC crop returns. Available areas of suitable soil types in different layouts provide constraints on some enterprises while others are imposed to represent capital and market constraints.
- Enterprise yields and variable costs—are specified for crop and livestock enterprises across different zones and irrigation layouts. Yields for pasture crops are provided on a seasonal basis. Data sources include departmental publications, research and extension staff and catchment planning initiatives. The majority of variable cost and yield data for enterprises are sourced from MIA and Districts Land and Water Management Planning evaluations (NSW Agriculture 1996b), and are specified for landformed border check and contour bay, non-landformed contour bay, and dryland layout classifications.

Water use requirements—these are defined for all crop and pasture activities on a monthly basis across different zones and irrigation layouts. Actual crop water requirements are driven by fluctuations in rainfall availability with monthly crop evapotranspiration requirements effectively fixed. The economic model is solved on the basis of annual farm-gate allocation availability, expressed as a percentage of licensed entitlement.

The Murrumbidgee catchment was sub-divided into eight separate production zones given below and shown in Figure 1. The zones cover four irrigation areas and districts, and four private diverter zones along sections of the Murrumbidgee River.

- Zone 1 – Murrumbidgee Irrigation Areas (Yanco and Mirrool)
- Zone 2 – Benerembah Irrigation District (including Tabbita)
- Zone 3 – Wah Wah Irrigation District
- Zone 4 – Coleambally Irrigation Area
- Zone 5 – Private Diverters: Burrinjuck Dam to Narrandera
- Zone 6 – Private Diverters: Narrandera to Hay
- Zone 7 – Private Diverters: Hay to Murray River
- Zone 8 – Private Diverters: Yanco and Billabong Creeks

The Murrumbidgee Irrigation Area (MIA) is comprised of Yanco Irrigation Area (centred on the town of Leeton) and Mirrool Irrigation Area (centred on the town of Griffith). The enterprises modelled are rice, vegetables (onions, carrots), soybeans, wheat, canola, lucerne (hay and pasture) and sub-clover. Although there are two major soil types within this region—red brown earths and grey self-mulching clays—similar enterprises and yields can be obtained from both with appropriate farm management practices. Thus, alternative soil types were not included in the model. Constraints apply to irrigation technology with 10% of the MIA landformed border check, 55% landformed contour bay and the remainder non-landformed contour bay. The licensed allocation for the MIA is 660,945 ML. The mean annual rainfall for Griffith is 396 mL.

Benerembah Irrigation District (which includes Tabbitta Irrigation District for the purpose of this study) is located adjacent to, and has similar soil types as, the MIA. The enterprises modelled are rice, vegetables (onions, carrots), soybeans, wheat, lucerne (hay and pasture) and sub-clover. The irrigable area is 42,827 ha with 15% landformed border check, 48% landformed contour bay and the remainder non-landformed contour bay. The licensed allocation for the region is 228,073 ML.

The Wah Wah Irrigation District is situated north-west of the MIA. The main enterprises are sub-clover, soybeans, wheat and rice. The irrigable area is 24,738 ha with 70% non-landformed, 18% landformed border check and 12% landformed contour bay. The licensed allocation is 116,279 ML.

The Coleambally Irrigation Area (CIA) is located to the south of the Murrumbidgee River. Unlike the above irrigation areas and districts, the CIA has three separate soil types specified in the model: unrestricted, marginal and restricted land. Unrestricted soils are predominantly clay and have no institutional restrictions on rice growing. Marginal soils, where only one rice crop is permitted every four years, are alluvial sands. Restricted soils, where no rice is permitted, are sandy soils. The areas of the three soil types are 60,347 ha of unrestricted soils, 6,112 ha of marginal soils and 11,160 ha of restricted soils. The irrigation layouts for unrestricted and restricted soils were assumed to be 6% landformed border check, 24% landformed contour bay and 70% non-landformed contour bay. Restricted soils were assumed to be 30% landformed border check and 70% non-landformed. The enterprises modelled for this region are rice, soybeans, wheat, canola, lucerne (hay and pasture) and sub-clover, depending on the particular irrigation layout and soil type. The licensed allocation is 446,699 ML.

The four private diverter zones cover the Murrumbidgee River from Burrinjuck Dam to its confluence with the Murray River. Accurate information on the nature of irrigated agriculture (crop and pasture areas, yields, rotations, irrigation layouts and efficiencies etc.) is very limited in these areas. Available information was used to calibrate models but significant uncertainties remain. For private diverter zones, it was assumed that each zone could produce soybeans, wheat, sub-clover, lucerne and summer pasture. Zones 6, 7 and 8 also included rice production. The layouts for each zone included landformed and non-landformed border check. Zone 8 also included landformed contour bay for specialised rice production.

The percentage of each irrigation layout for each zone of the private diverters region is as follows:

- Zone 5: 60% non-landformed border check and 40% landformed border check;
- Zone 6: 90% non-landformed border check and 10% landformed border check;
- Zone 7: 90% non-landformed border check and 10% landformed border check; and
- Zone 8: 75% non-landformed border check and 12.5% each of landformed border check and landformed contour bay.

The licensed allocations are 47,490, 190,158, 283,719 and 78,641 ML for Zones 5 to 8, respectively. Zone 9, which is the Lowbidgee private diverter zone, does not have a licensed allocation, relying on off-allocation supplies. It has been excluded from the analysis because accurate hydrology data on the extent of irrigation diversions under different environmental scenarios are not available.

Modelling the Farm Level Implications of Water Reforms in NSW, Australia

Jason Crean and Rob Young*

Abstract

The New South Wales (NSW) Government is in the process of implementing a comprehensive water reform program aimed at improving the health of NSW rivers, estuaries and groundwater. Re-balancing of increasingly scarce resources amongst users has coincided with increasing recognition by government and community of the importance of considering socioeconomic effects of policy change. The consideration of the socioeconomic effects of water management decisions is an integral part of the NSW water reform process.

NSW Agriculture has principal responsibility for assessing the farm-level economic impact of water reform options. This has involved working with water management committees to evaluate the impacts of a number of water management plan elements. A representative farm modelling approach has been adopted to provide information on the magnitude and distribution of these impacts. The paucity of data about the nature of irrigated farming at a farming system scale can pose a significant constraint to the development of these models. This paper looks at how some of the difficulties can be overcome through the collection and integration of data sets ranging from simple consensus data techniques through to more sophisticated remote sensing and GIS-based approaches.

POLICY reform in the Australian water industry has received considerable attention in recent years. This can be partly attributed to growing community concerns regarding the declining environmental health of rivers and wetlands, increasing evidence of the poor state of land resources in irrigation areas, increasing competition between users and greater government focus on improving economic efficiency through microeconomic reform. A significant milestone in the changing focus of water resource management in Australia was the agreement by the Council of Australian Governments (COAG) in 1994 to a strategic framework of water-policy reforms. The framework aims to maximise the economic contribution of water to the Australian community and achieve a better balance between environmental and consumptive uses.

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Implementation of the COAG water reform framework rests with State governments who have constitutional responsibility for managing natural resources, including water. New South Wales (NSW), like other States, is in the process of implementing these reforms, which fundamentally change the way water is priced, allocated and traded. A consideration of socioeconomic effects of policy change and the establishment of a community driven approach to policy implementation have been important ingredients in the NSW water reform process. Natural resource management agencies, like NSW Agriculture, provide support to this approach including assistance in assessing the socioeconomic trade-offs associated with water management options.

NSW Agriculture is primarily responsible for assessing the farm-level impacts of water reform. The department works closely with community-based committees to evaluate the agricultural impacts associated with implementing water-policy reforms. The impacts on agriculture are of particular concern in NSW, due to the State's historically less conservative approach to the allocation of water to extractive uses. That is, water has been over-allocated to the irrigation industry and the government is now needs to claw back entitlements.

The evaluation of agricultural impacts can be undertaken at a catchment scale[1] to highlight intersectoral trade-offs or at a more disaggregated level to indicate how impacts might be distributed between typical groups within the agricultural sector. The latter is the subject of this paper. The objective of this paper is to outline the approach adopted by NSW Agriculture to quantifying the farm-level economic impacts of water-policy reform and how this fits into the community- based approach to water reform adopted in NSW. In particular, the paper describes data collection processes used to define the nature of irrigated farming systems which is critical to the evaluation of water policy changes.

The paper is structured as follows. The next section provides background information on water resource management in NSW, the evolving nature of water-policy reform, and the community-based approach to water reform adopted in NSW and the role of NSW Agriculture in that process. This is followed by a description of our methodological approach to assessing water reform issues based on the development of representative farm models. Some of the data requirements for undertaking this type of analysis, data constraints encountered and some of the methods used to overcome these constraints are then described. Finally, some conclusions and recommendations are presented in the last section.

Water Management in NSW

Irrigated agriculture in NSW

The irrigation sector in NSW relies principally on surface water from regulated and unregulated rivers and streams. In some parts of the State, notably the northern inland, groundwater resources are also important. Figure 1 shows the major regulated[2] and unregulated streams, main dams and principal irrigation development in NSW. Regulated water supplies underpin the majority of irrigated agriculture in the State. There are 16 major dams and other storages on regulated rivers in NSW, with a combined storage capacity of over 14 million ML (DLWC 2000a).

The majority of rainfall in NSW occurs on the Great Dividing Range and the narrow coastal plain along the east coast. Rainfall is lower and more variable to the west of the mountains (400–650 mm per annum in the main cropping zone) and evaporation is higher (2,000–2,500 mm per annum). As a result, irrigation development has focused on the major inland river systems. Around 80% of total water use occurs in inland NSW and approximately 90% of this is used for irrigation. Figure 2 shows the dominance of water used by irrigation relative to other users in the regulated catchments of inland NSW. It also highlights the concentration of water use in southern NSW in the Murrumbidgee and Murray Valleys, a major focus of early government-funded irrigation development schemes.

NSW has a large and productive irrigation sector growing a mixture of broadacre crops (rice, cotton and winter cereals), annual and permanent horticulture (grapes and fruit) and pastures to support livestock enterprises. The annual value of irrigated production in NSW is more than $2 billion and the industry is a major contributor to regional economies in rural NSW. There are significant variations in the types of enterprises grown across different catchments, differences in the types of irrigation systems used (from flood irrigation to high-technology drip systems), wide variations in irrigation demands driven by climatic variability and differing levels of irrigation reliability.

There are also key differences in the nature of irrigated farming systems in the northern and southern parts of the State. Rainfall is winter-dominant in southern NSW meaning that summer cropping demands are reasonably predictable. Reliable irrigation supplies are received from a number of large storages, some of which are supplemented with diversions from the Snowy Mountains area. Irrigation has been long established in these areas, and rice is the most significant irrigated crop. This situation can be contrasted with that of northern NSW which has summer-dominant rainfall, creating variable summer water demands. Irrigation supplies are also much more uncertain in the north of the State reflecting a greater intensity of water use, a lower overall level of river regulation and more variable climatic conditions.

1. An example of this is given in the paper by Crean, Jayasuriya and Jones in this volume.

2. Most major inland rivers in NSW are regulated. Regulated rivers are those whose supply is controlled or augmented by releases from dams and weirs operated by the Department of Land and Water Conservation. People using this water must have a licence which allows them to take a certain amount of water each year.

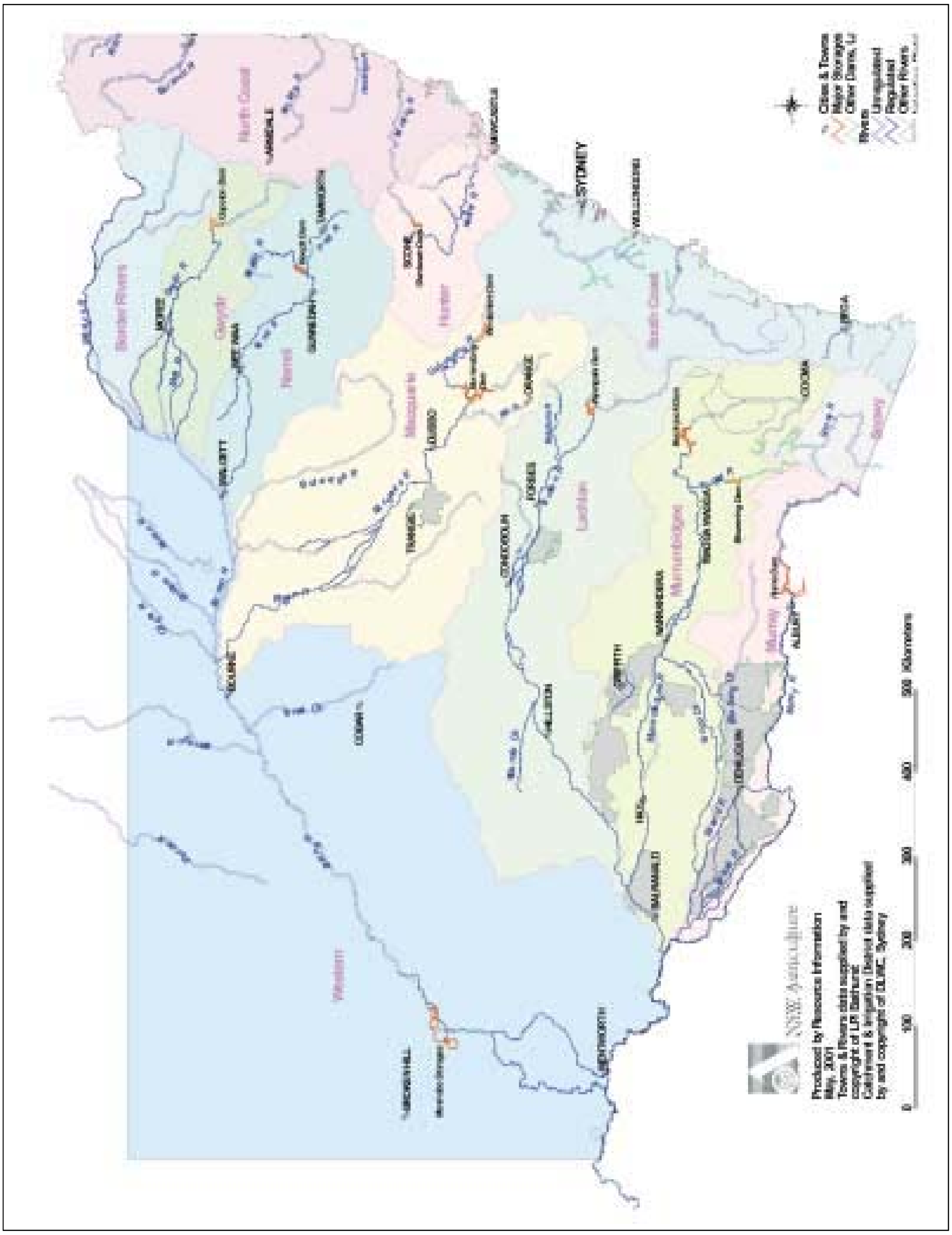

Figure 1. New South Wales showing major catchments and regulated rivers.

These conditions have made water a relatively scarcer resource in northern NSW. Irrigation development has also been much more recent and many of the irrigation farming systems involve cotton production.

Historical policy context

Publicly funded irrigation development in NSW became commonplace from the late 19th century. Irrigation development was closely associated with closer settlement policies that involved the allocation of small agricultural holdings, complete with water supply and drainage facilities, to new settlers. Such irrigation schemes were seen as an appropriate public investment to overcome climatic limitations associated with dryland agricultural production and to populate the inland of the continent. The benefits of irrigation development were largely unquestioned and substantial government investment in large irrigation storages and distribution networks attracted widespread public support (Musgraveet al. 2000)

By the 1960s, however, most of the highest-yielding and more cost-efficient storage sites had been utilised. Continuing public investment in irrigation infrastructure came under increasing scrutiny, particularly by economists (Davidson 1969) as schemes failed to recover the full cost of water supply. Highly subsidised water supplies not only caused fiscal pressure on government, but encouraged inefficient use which, in turn, led to increasing problems with water logging, salinisation, and soil structural decline in major irrigation areas. By the 1980s, questions also started to be raised about the ability of rivers to support further levels of development, as environmental concerns[3] began to emerge (DLWC 2000a). The collective weight of community concern led to significant policy shifts away from further resource development towards improving the efficiency of existing irrigation development and managing the increasing problem of resource degradation. Economists were influential in these debates, recognising that the Australian water economy was entering a mature phase where the issues, priorities and costs of solutions were significantly different from those in the early expansionary phase (Watson and Rose 1980; Randall 1981).

Water management in NSW has been under constant review since the mid 1980s. Between 1984 and 1995 there were 10 major reports on the NSW water industry, most of these arising from independent inquiries established by the government (DLWC 1999). These reviews have been complemented by a large number of inquiries undertaken at a Commonwealth level, as well as reports of joint State and Commonwealth institutions including the Murray–Darling Basin Commission. This potted history of water management policy in NSW provides a picture of water

3. Thoms and Cullen (1998) discuss the environmental impacts of irrigation extractions on inland rivers.

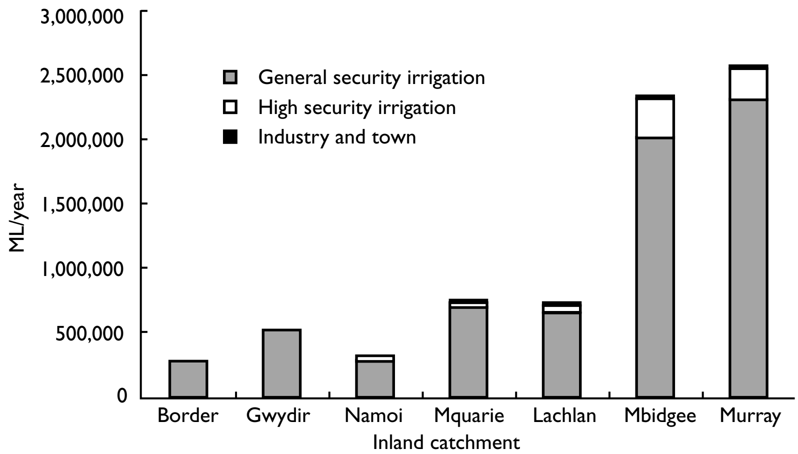

Figure 2. Average surface water use for inland catchments of NSW (1987–1997). Source: DLWC (2000a, p.9).

reform as a gradual process rather than one of overnight change.

Current water policy reforms

The pace of water policy reform increased in the mid 1990s following agreement by the Commonwealth and all State governments to the Council of Australian Governments (COAG) water reform framework.[4] NSW is in the process of implementing this framework which includes the following components:

- pricing based on principles of full-cost recovery and transparency;
- comprehensive systems of water allocations, backed by separation of water property rights from land title;
- formal determination of water allocations including allocations for the environment;
- trading, including cross-border sales of water allocations or entitlements;
- institutional and organisational reforms involving the separation of resource management and regulatory roles of government from roles of providing water services; and
- improved public participation and community consultation in water management decisions.

The implementation of many aspects of the COAG framework is likely to pose more difficulties for water users in NSW relative to other States. This is because, historically, NSW has adopted a less conservative approach to the allocation of water resources. Many surface and groundwater systems have been over-committed in terms of sustainable resource limits (NLWRAAC 2001). The over-commitment of water resources has not only led to environmental degradation, but also has established the basis for conflict not only between irrigators and other sectors of the community but between different irrigator groups on who should bear the burden of reduced access to water—for example, between active and inactive entitlement holders, between different commodity groups and between irrigators on regulated and unregulated sections of the same river.

Key features of the COAG framework currently being implemented in NSW are as follows:

- The introduction of a 'cap' on water diversions in the Murray–Darling Basin (which includes most inland rivers in NSW) based on 1993–94 levels of irrigation development.
- The allocation of up to 10% of average annual diversions back to the environment in all inland regulated catchments.
- A reduction in irrigator access to low flows in unregulated streams in order to minimise environmental impacts at times of natural environmental stress (low flows are also the time of peak irrigation demand).
- Management of groundwater reserves on a sustainable yield basis to protect users from further declines in groundwater quantity and quality, ensure the sustainability of groundwater dependant ecosystems and to avoid the possibility of aquifer collapse. In some groundwater aquifers this will result in a significant reduction in entitlements.
- Water prices have been put on a path towards full cost recovery, resulting in price increases across the State.
- Water markets are being further expanded to encourage more efficient use and allow the transfer of water from low to high value uses.

Community involvement and socioeconomic assessment

The NSW Government is articulating water reforms as a whole-of-government and whole-of-community partnership in managing the State's water resources. Key to the community's involvement in water reform is the establishment of community-based water management committees (WMCs) for each major catchment and aquifer system. The committees have an independent chair with members drawn from water users, conservation groups, Aboriginal people, local government, catchment management boards and NSW Government agencies involved in natural resource management. All committees have a majority of community members.

[4] It is worth noting that many of the reforms contained in the COAG water reform framework had been raised in previous reviews and studies. The essential difference between this framework and others is the endorsement by all States to its principles and its formal linking to the Commonwealth Government's National Comp-etition Policy (NCP). The latter is of a particular significance because States receive tranche payments from the Commonwealth Government for imple-mentation of the NCP which total $16 billion.

Government responses to natural resource management problems in NSW and Australia are increasingly adopting more community-based approaches.[5] These responses represent some departure from the traditional 'top down' approaches to problem solving to so called 'bottom up' approaches which are characterised by community involvement in the development and implementation of local solutions to local problems. Attwater (1995) suggests that Australia is not alone in this paradigm shift, with participatory approaches to rural development and catchment management developing throughout the world.

Some authors suggest that the move towards community-based approaches reflects a principle that complex problems are best researched with people, rather than for people. Bellamy and Johnson (1997) identify a number of issues contributing to a shift in focus including:

- the need for the active involvement of the whole community that leads to community ownership of the problem and its solution, and ultimately the adoption of sustainable resource use and management practices;
- the need for coordination of decision-making amongst stakeholders in government, industry and the community;
- the concept of the 'whole being more than the sum of the parts';
- the realisation that people are an integral part of the problem and not external to it; and
- increasing community expectations for greater involvement in decision-making and higher standards of accountability in environmental protection.

The main task of water management committees, in the context of the community-based approach adopted in NSW[6], is to develop water management plans for the local implementation of water-policy reforms. These plans will be in place for 10 years, providing security for resource users for that period. For the regulated rivers, the key issue to date has been defining environmental flow rules (specific volumetric allocations as well as manipulating storage releases to best suit the environment). On the unregulated rivers, the focus has been on converting area-based licences to volumetric licences, determining how these translate into flow shares and how to reduce extractions during periods of low or zero flows. For groundwater resources, modifying access rights to achieve sustainable aquifer management has been the dominant issue. However, water management plans are also required to address the interaction between water quality and flow issues. Attention is expected to turn to water quality issues once flow issues have been addressed, although some improvement in water quality is expected as a direct result of environmental flows included in the flow sharing plans.

In developing management plans, the committees are required to consider the environmental, economic and social consequences of planning options and develop a plan which best achieves a balance between those outcomes. Guidelines have been prepared to assist WMCs implement this process (IACSEA 1998). In most cases, the trade-offs between environmental, economic and social impacts will be made on a qualitative basis by committee members, based on available information and expert opinion. This will be supplemented by quantitative analyses on the hydrological impacts of planning options, specific environmental studies and economic and social analyses. NSW Agriculture employs four economists to undertake economic analyses of the impacts of water planning options on irrigated agriculture on behalf of WMCs. The Department of Land and Water Conservation (DLWC) and the Environment Protection Authority (EPA) have also received additional resources to undertake economic assessment on environmental outcomes, other water users (towns, industry, tourism, fisheries) and to undertake social impact assessment.

Assessing the Economic Impact of Water Policy Changes

Economic trade-offs

Water-policy reforms generally involve some form of modification of property rights (real or perceived) involving a re-allocation of resources. Resource re-allocation decisions are commonly assessed in a benefit–cost framework. The economic

5. As noted by Byrne (1997), 'there is a continuum of institutions, rather than sharp dividing lines between government and community'. We define community based approaches as ones encompassing more genuine attempts at involving stakeholders in natural resource management decisions.

6. The adoption of a community based approaches in the NSW water reforms is described in Crean, Pagan and Curthoys (1999).

efficiency of different allocation policies can be assessed by comparing the social benefits and costs associated with each policy. Underpinning the benefit–cost framework is the 'potential Pareto improvement' criterion which states that resource re-allocation decisions are efficient if those who are made better off can compensate those who are made worse off and still be in a better situation. Of course, for the criterion to be satisfied it is not necessary for compensation to be actually paid.

There are, however, a number of difficulties associated with adopting the standard benefit–cost analysis framework when considering issues that are likely to yield environmental benefits, like increased allocations to the environment. The major difficulty relates to the appropriate valuation of environmental benefits (particularly those in the non-use category) so that they can be incorporated into a benefit–cost framework. To overcome some of the conceptual arguments regarding valuation, a variation on the standard benefit–cost framework can be adopted through the use of an 'opportunity cost' or 'threshold value' approach. The threshold value approach avoids the need to directly place monetary values on environmental goods. The approach is based upon estimating the 'opportunity costs' which would be the consequence of a particular resource decision. The opportunity costs are then directly compared with the environmental outcomes (quantified in non-monetary terms) that are expected from the proposal.

There are, however, further difficulties in applying a modified benefit–cost approach to community planning processes like the NSW water reforms. These relate principally to the broader interests of the community beyond economic efficiency. WMCs also consider whether water management changes are 'fair and reasonable', incorporating notions of equity between water users. Of key concern to many stakeholders is how the impacts of water management changes are distributed amongst different users. These users may be defined on a range of criteria including a geographic basis (e.g. users in a specific part of a catchment) or a particular subset of users defined on water usage (e.g. more active irrigators) or property or entitlement sizes (e.g. small users).

The evaluation of agricultural impacts therefore requires analysis at two levels. First, at a broader regional scale, agricultural impacts can be assessed and subsequently used in a threshold value approach to determine the overall economic efficiency of options. Second, impacts on a more disaggregated basis can be assessed to provide WMCs with distributional information on how subsets of the population might be affected. NSW Agriculture has undertaken economic assessments at both levels. The first issue is discussed in another paper in this volume (Crean et al., these proceedings) while the latter issue is the focus of the following sections of this paper.

Selection of a methodology for assessing farm level impacts

There is a broad range of techniques available for assessing the farm-level impacts of water-policy reforms. These techniques range from simple budgeting methods to formal optimisation models. The applicability and appropriateness of any of these techniques depend ultimately on the context of the analysis, the problem being addressed and the nature of the farming systems under consideration. These issues are discussed below.

The community-based approach to the implementation of water reforms provides the overall context for farm-level analyses undertaken by NSW Agriculture. The purpose of quantitative work within this context is to facilitate social choice. More specifically, it is to provide information to help WMCs understand how the farm-level financial impacts of water planning options are distributed so that appropriate trade-offs can be made. The central role that WMCs have in the process and their broad community representation (with varying levels of understanding of economics) suggest that relatively straightforward methodological approaches should be used. Methodological approaches should meet simplicity and transparency requirements while also remaining sufficiently rigorous to capture real effects.

The nature of the problem has a key influence on the suitability of approaches. The types of problems proposed by WMCs commonly involve some form of restriction to the access of water resources. The significance of these restrictions will depend on climatic conditions which influence both the availability of resources for extraction and resource demands. When climatic variability is likely to influence the relative effects of water management options, then more stochastic methodologies are required (e.g. simulation).

Restrictions in an important farm resource like water also may not be constrained to a single agricultural activity but rather have whole-farm implications. Often there are important interactions between farm resources and on-farm activities. For this reason, it is appealing for these problems to be considered in a whole-farm context so that farm adjustment responses can be better understood and assessed.

The nature of the problem will also have implications as to whether it can be represented in a static or dynamic framework. A static methodology is one that does not consider the temporal aspect of a problem. If a problem requires the determination of the optimal allocation of a resource over time or the evaluation of impacts of strategies over a given horizon, then a dynamic methodology should be used (Vere et al. 1997). These types of problems are common in resource management and can be evaluated in multi-period budgeting, optimisation (dynamic programming and multi-period LP) and simulation approaches.

Generally, there is a series of options for how water management committees can apply restrictions on access to water resources. These options often evolve during the planning process. Methodological approaches therefore need some degree of flexibility to incorporate new options with relative ease.

The nature of farming systems[7] also has implications for what types of approaches are most appropriate. Farquharson and Scott (2000) argue that farming system groups are the most appropriate means of classifying the population because the similarities in their farming resources and methods, mean they have similar response options. For example, there are significant differences in irrigation farming systems between northern and southern NSW. These relate not only to different rainfall seasonality but also to the reliability of irrigation supplies, irrigation methods and on-farm infrastructure. These differences should be reflected so that the essence of the problem can be fully understood in the context of a typical farming system. Another important factor in representing the farming system is the need to capture how farmers respond to change and this requires careful consideration of the strengths and weaknesses of optimisation versus less formal decision rule approaches.

Consideration of the issues raised above has led to a mixture of approaches being adopted in NSW to the evaluation of farm-level impacts. In broad terms, these can be categorised as whole-farm simulation approaches. The models attempt to represent a typical or representative farm. They have been developed as spreadsheet-based models and are generally more readily understood by committee members compared with many other approaches. They report the consequences of water policy options in terms of farm performance measures including whole-farm gross margin and net farm income. Simulation is used to represent irrigation requirements and the availability of irrigation water. Irrigation requirements are driven by fluctuations in rainfall availability with monthly crop evapotranspiration requirements fixed. DLWC hydrology simulation data are used to represent irrigation water availability over the same period. A typical model structure for evaluating farm-level impacts is illustrated in Figure 3.

It is important to note that the objective of the analysis is to simulate the impact of various water policy and planning options on farm financial performance. It is not to comprehensively model all the complex biophysical, cultural and financial interrelationships inherent in all agricultural systems. The models used are a simplification of reality designed to isolate and consider impacts related to water reform.

Farm responses to changes in water availability are determined either directly using key decision rules elicited from irrigators and technical experts, or indirectly by using formal optimisation models such as linear programming. Concerns over the use of mathematical programming have been well documented in the literature.[8] Hardaker (1979) noted that many quantitative approaches (like programming) suffer from the 'curse of dimensionality' referring to the difficulty in adequately accounting for all the complexities involved in farm management. However, many of the criticisms of these techniques are made in terms of their contribution to solving actual farm-management

7. We use the words 'farming systems' to denote that there are various components to farming and the interactions between these components are often important in understanding behaviour. The recognition of a particular farming system suggests that there is some basic level of homogeneity in the resource constraints and opportunities available to the farm, some consistencies in how farmers would generally behave to changes in their operating environment and some accepted ways of managing interactions.

8. Examples of criticisms can be found in Makeham and Malcolm (1993), Dent et al. (1986) and Hardaker (1979).

problems rather than policy applications. The development and evolution of better policy options requires the use of methods which provide some general insights into farm behaviour, rather than presenting a course of action for an individual farm.

We have found that each method of incorporating farm responses to policy changes has both advantages and disadvantages in terms of model development and scenario evaluation. The decision rule approach is often preferred by irrigators and committee members who distrust mathematical programming models because the method is not readily transparent. Directly elicited adjustment responses are simpler to obtain and build into economic models, as the number of options considered is generally smaller. However, this approach also has a number of shortcomings including:

- strategic behaviour (cooperators providing false responses designed to influence the outcomes of the study and consequent policy decisions in their favour);
- responses are often only relevant given the prevailing input and output relationships; and
- farmers have often not fully considered the options they nominate (options are often only fully considered when their implementation is imminent rather than simply a possibility).

NSW Agriculture has used both decision rules and formal optimisation approaches. Initially, committees and irrigators have preferred to nominate adjustment responses. However, responses proposed have sometimes proved unlikely in particular circumstances, reflecting some of the shortcomings outlined above. The occurrence of problems with decision rule

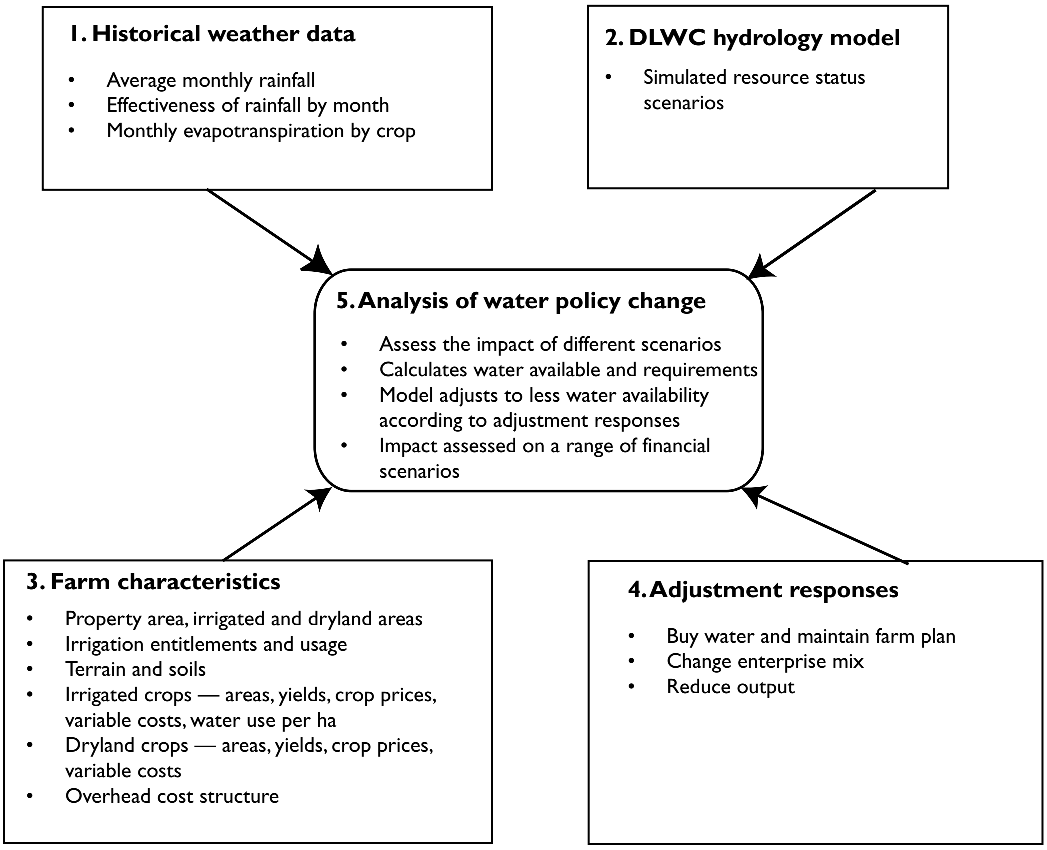

Figure 3. Outline of model structure—evaluating environmental flow scenarios.

approaches has sometimes provided a basis for the acceptance of more sophisticated optimisation approaches. However, trust of committee and stakeholder groups needs to be developed and the limitations of optimisation methods understood before such approaches are accepted.

Development of Representative Farm Models

The development and application of whole-farm simulation models requires the collection of a range of data as defined in the model structure outlined in Figure 3. These data will be used firstly to distinguish different farming systems to be analysed and secondly to define representative farm models for each farming system for analysis. The following discussion outlines the general sources of data available for the development of representative farm models in NSW and discusses our approach to the collection and integration of data sets in the context of the community-based approach to water reforms. These data issues are then illustrated by reference to a study undertaken by NSW Agriculture into the management of groundwater resources in the Namoi Valley in northern NSW.

Sources of data

Data for specifying representative farm models are potentially available from a range of sources. This might include previous specific collections located through a literature review and more widely available secondary statistics collected by government agencies. Generally, these data are readily available and can be accessed at a non-prohibitive cost. However, because such data are collected for other reasons, they will not always be suitable for the specific problem at hand in the location under study.

In many circumstances, existing data at a sufficiently disaggregated level will not be available and additional data collection will be required. There is a variety of methods for collecting some or all of these data and these are discussed below.

Census

A census of all affected population members is the most accurate means of obtaining data (ABS 1993). The results have the greatest credibility both with community members and policy-makers and can be aggregated or disaggregated to an appropriate level. Because a census involves the collection of data from the entire population, it is often the most expensive and time-consuming means of obtaining such data. There are also legal issues involved in compelling respondent cooperation. For these reasons, censuses are rarely used to obtain data for specific studies.

Survey

Surveys are widely used to obtain detailed data from a sample of the population. If the questionnaire is well designed, appropriate statistical sampling techniques are used and data are reliably collated, surveys can provide more in-depth information than a census at a lower cost. Properly designed surveys should achieve credibility both with the community and policy makers. However, there are still considerable costs and time involved in survey design, collection of data and collation of results. Actual costs will depend on the size of the survey, the detail of the questionnaire and how it is implemented (face to face, telephone, mail). Each collection method introduces various sources of bias (ABS 1993).

Local consensus data

The local consensus data (LCD) technique involves a small group of experienced farmers meeting with local agricultural extension staff and a facilitator to define physical and financial data for a 'typical' farm. As discussion proceeds, a consensus of opinion or agreement is reached on the attributes and production relationships of the 'typical farm' (see Figure 3). Published statistical data (such as farm size, irrigation entitlement) should be used to guide discussion and to validate collected data.

The technique can be quick and cost effective. It is particularly relevant where there is a paucity of census or survey data available and the cost and time requirement for using such methods is prohibitive. The credibility of results is usually high amongst stakeholders, as they are involved in data collection. Credibility among other stakeholders and policy-makers can be enhanced by ensuring that key attributes are cross-referenced to published statistical data. The approach is not statistically based and is therefore not truly representative of farms on the basis of any single characteristic. Figures derived cannot therefore simply be aggregated to determine regional impacts. A particular advantage of the LCD approach in light of the community-based approach to water management in NSW is the participation of stakeholders and committee members. This helps achieve acceptance, not only of results, but the policy outcomes. A more detailed discussion on the technique and its relative advantages and disadvantages can be found in Jayasuriya et al. (1999).

Case study

The farm case-study approach involves the collection of detailed farm data for one or a few farms. The objective of the case-study approach is to learn not only what is physically happening on the farm but the cause and effect relationships. Dillon and Hardaker (1980) suggest that gauging farmer responses to policy change sometimes requires an in-depth study of the realities of farm production and of farmers' attitudes. A case-study approach is the most feasible option in these circumstances. Malcolm (2000) also supports the use of case studies to gain an understanding of particular issues driving key management decisions as farmers adjust to the forces of change continually impacting on their business.

The farm case-study approach varies from the LCD approach as data collection does not rely on a consensus decision by farmers. Consensus can be difficult to achieve in areas where there is significant variability in farm types and resource constraints. Other advantages of case studies relate to the collection of 'real' rather than hypothetical farm data, a better understanding of farmer responses to change and greater levels of participation in the research by stakeholders and hence acceptance by them of results.

However, case-study farms are unlikely to be statistically representative of their particular area. As a result, figures derived cannot be simply aggregated to determine regional impacts. It is also possible that the financial performance of individual case-study farms will reveal more about the peculiarities of those farms and their owners/managers than about the issue being evaluated. Results therefore need to be interpreted carefully.

Satellite image analysis

Satellite image analysis can be used to describe some of the key physical attributes of farming systems. High-quality imagery is now available at a reasonable cost for most locations. The spectral bands captured on most satellite systems are designed (among other uses) for the analysis of agricultural land use. However, typical spatial resolution of satellite imagery (30 m pixels) is such that land uses of below 10 ha are difficult to interpret. For smaller-scale agriculture, greater resolution satellite imagery or alternative appraisal methods are necessary. Field validation is required to ensure accurate image interpretation.

A case study of groundwater management in northern NSW

The following case study on groundwater management in the Namoi Valley of northern NSW provides some background information on the nature of the policy issue being addressed, then discusses data sources to provide the information requirements set out in Figure 3.

Background to groundwater management in the Namoi Valley

The groundwater resources of the Namoi Valley are significantly over-allocated and, in many of the management zones, over-used. Current usage levels in several zones far exceed aquifer recharge rates. Groundwater levels are falling and, if current use continues, could be exhausted within 30 years in some management zones (NGERP 1999).

The NSW Government has developed a draft groundwater policy (DLWC 2000b) which requires total licensed entitlement in each management zone to be less than average annual recharge. This will mean reductions of more than 50% in current usage by some irrigators. NSW Agriculture has undertaken an analysis for the Namoi Groundwater Management Committee (NGMC) to evaluate the farm-level impact of various management strategies by which sustainable groundwater use can be achieved. Of particular interest to the committee is how the impacts of strategy options might be distributed among different groundwater users.

There is a range of different options to address groundwater over-allocation in the Namoi Valley. The NGMC proposed a number of strategies for evaluation including:

- an across-the-board reduction to all entitlements;
- giving active irrigators preference by weighting the reductions more heavily for inactive licence holders;
- phasing-in entitlement reductions over several years;
- introducing carry-over provisions for unused entitlement; and

- introducing trading arrangements to allow irrigators to autonomously adjust.

The strategies proposed provide some guidance for the development of representative farm models and some guidance as to the issues that will require evaluation within a modelling framework. A representation of the following aspects is required:

- different groundwater management zones (which face different impact levels);
- different levels of activation of entitlement; and
- impacts over time (to account for carry-over and phase-in provisions).

The location of the major aquifer systems in the Namoi Valley and the management zones within that aquifer are illustrated in Figure 4.

Historical weather data (Box 1 in Figure 3)

Climatic data are required to simulate the irrigation requirements for crops and pastures. These data are collected across Australia by the Bureau of Meteorology. Because of inconsistencies in data collection, simulation and interpolation are required for missing or inaccurate data. Key climatic variables for the Namoi Valley are summarised in Table 1. This shows that rainfall is 40% lower in the west of the study area and evaporation is 26% higher. This has implications for irrigation demand, and suggests different irrigated farming systems may need to be defined for the east of the study area from those in the west. Data on monthly evapotranspiration are crop specific and were derived using the Penman–Monteith equation (Allen et al. 1998). Crop coefficients for the study area were provided by the Water Use Efficiency Unit at Dubbo (N. Austin, NSW Agriculture, Dubbo, pers. comm.).

Table 1. Key climatic data for the Namoi Valley of New South Wales.

Location	Mean annual rainfall (mm)	Mean annual evaporation (mm)
Tamworth	664	1,963
Gunnedah	605	1,952
Narrabri	640	2,024
Walgett	476	2,475

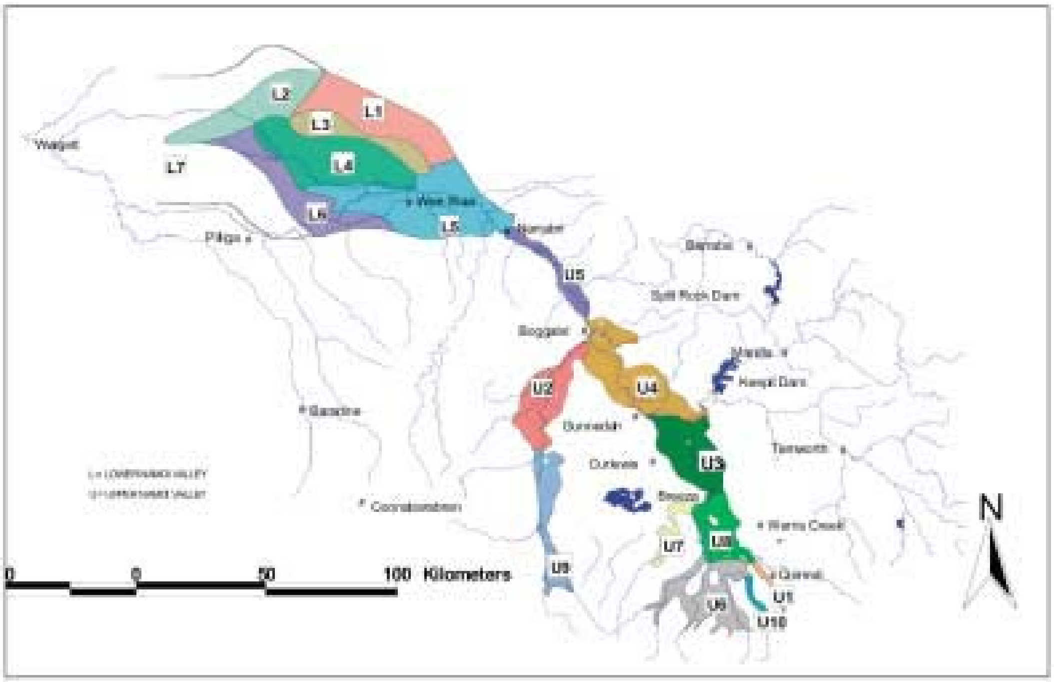

Figure 4. Groundwater management zones for the upper and lower Namoi Valley.

Hydrology data (Box 2 in Figure 3)

Hydrology data are the responsibility of DLWC for both surface and groundwater in NSW. The department has developed hydrology models for each regulated river in NSW as well as for major unregulated rivers and is in the process of developing models for other high-priority unregulated systems. Hydrogeological models are also under development for major groundwater aquifers, although these are generally not as well advanced as most surface water models.

Under the community-based water reform process, DLWC hydrologists model the hydrological impact of planning options under consideration by WMCs. These data are also provided to NSW Agriculture for incorporation into representative farm models. In the case of groundwater resources in the Namoi, such data included current modelled estimates of sustainable yield for each groundwater management zone. The sustainable yield for zones in the Upper Namoi, along with data on recent use and total issued entitlement, are provided in Figure 5.

Figure 5 indicates that Zones 1, 3 and 8 in the Upper Namoi are not only severely over-allocated but also over-used. However, usage in Zones 6, 7, 9 and 10 is currently less than sustainable yield. Irrigators in some zones will face significant reductions to entitlement and current use levels, some will be relatively unaffected while others can actually increase current groundwater use. This highlights the need to develop representative farm models capable of evaluating the impact on different aquifer zones. The data in Figure 5 also highlight the zones for which more detailed analysis is required. Zone 3 is likely to suffer the most severe impacts from groundwater reallocation. The remainder of this section uses Zone 3 to illustrate data collection issues.

Farm characteristics data (Box 3 in Figure 3)

The development of representative farm models requires the collection and integration of a range of data. In general terms, this requires data to be captured on the physical resources available to the farm, the extent and profitability of existing land uses and some appreciation of financial attributes of farms. This section is broken up into two parts. The first describes the collection of data on the key characteristics of farms in Zone 3 of the Namoi Valley, while

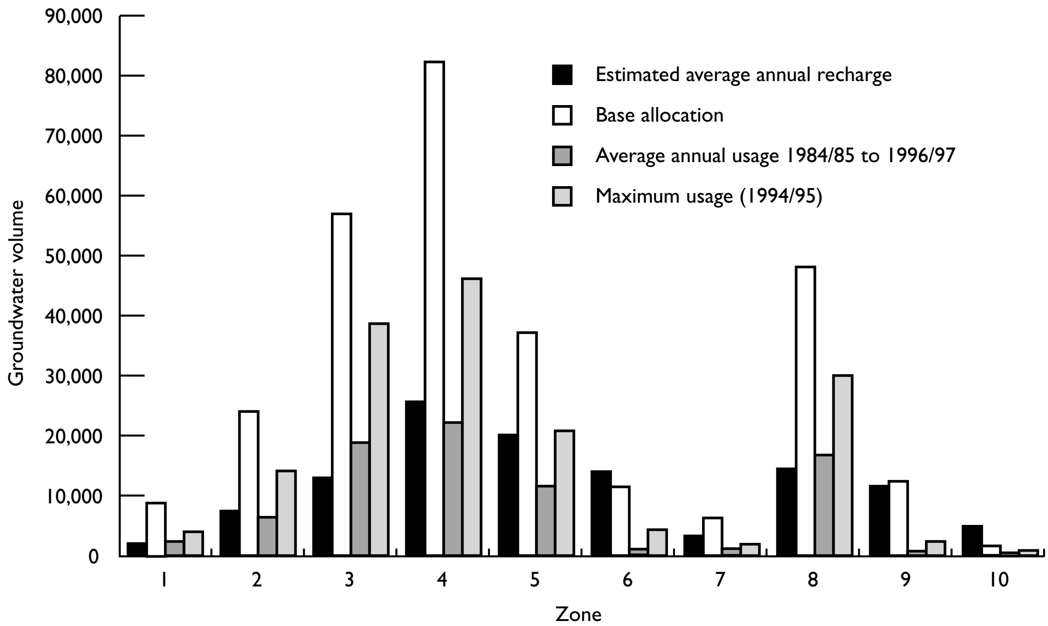

Figure 5. Groundwater allocation, recharge and use in the upper Namoi Valley.

the second outlines the process used for the integration of that data.

Farm data collection

Irrigation entitlements and usage. DLWC provided a database of individual groundwater entitlements and historical metered water use since 1994–85. These data are illustrated in Figure 6 for groundwater licence holders in Zone 3. It suggests there is considerable variability in both the size of entitlements ('base allocation') and in the level of activation of those entitlements ('Ave use 95–97').

Landscape and soil type. Landscape and soil data were obtained from maps provided by DLWC (Banks 1995). These showed that over 95% of irrigation development in Zone 3 occurs on the 'floodplain' landscape unit. There were two predominant soil types used for irrigation development. Approximately 85% of irrigation took place on black cracking clays while the remaining 15% occurred on brown and grey clays. Both soils are highly fertile and among Australia's most productive soils. The black cracking clays are more inherently fertile and have a better soil structure and moisture holding capacity (Banks 1995). This level of homogeneity in physical attributes, particularly in relation to soil type, is less common in a number of other irrigation areas, such as those in southern NSW. This highlights the need to adopt techniques capable of accurately specifying the landscape and soil types where irrigation is undertaken. This is discussed in greater detail below.

Property size and land use. Information on property size and land use is a key data requirement for defining farming systems. The Australian Bureau of Statistics (ABS) collects data on property size and land use as part of the national 'Agricultural Census' every 5 years (ABS 1999). Unfortunately, these data are available only at a level of disaggregation broader than is required for irrigation farming systems. As a result, these averaged results are of little value in defining representative farms for groundwater users in the Namoi Valley.

To overcome these deficiencies a local census data (LCD) approach was applied in two stages. Stage 1 was to meet with local resource managers and advisers from NSW Agriculture and DLWC along with farmer members of the WMC to identify the types of farming systems to be targeted. Stage 2 involved a meeting between the LCD group and irrigators and local advisers. The first stage identified 8 broad irri-

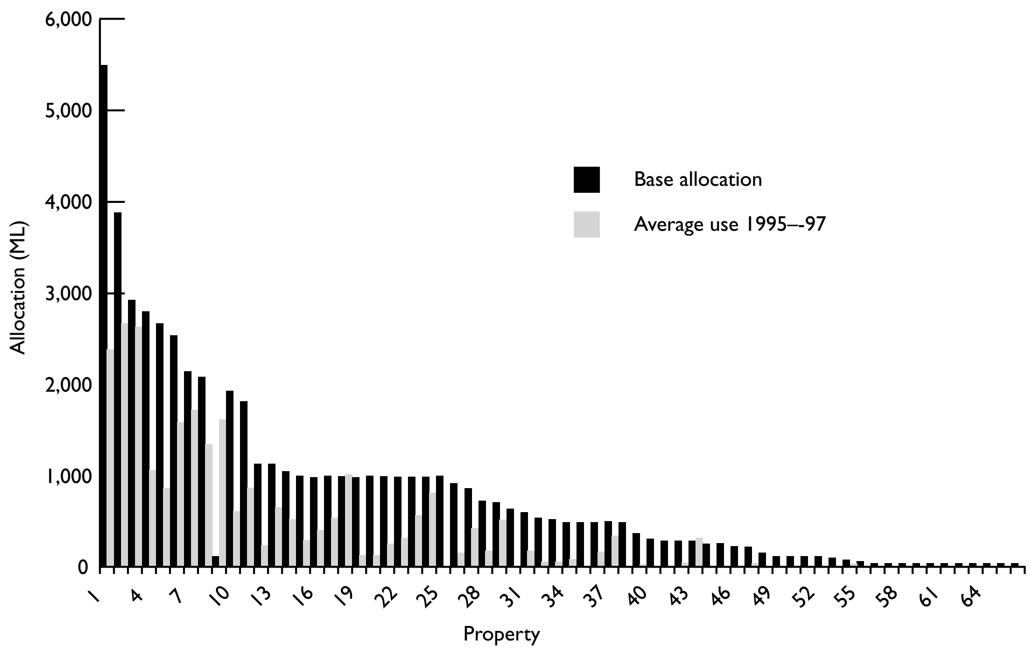

Figure 6. Allocations and use for upper Namoi Zone 3 irrigators.

gated farming systems in the Namoi Valley. One of these (shown below) corresponded closely to farming systems in Zone 3.

A LCD workshop for stage 2 of the process was subsequently held in Gunnedah. Unfortunately, irrigators attending this workshop were unable to reach consensus on the key physical characteristics of a representative farm (size, irrigation entitlement, licence activation). This was partly due to an absence of objective data on the nature of local farming systems to guide discussion and partly because of pre-existing conflict between some irrigator members of the LCD group. This highlighted two issues. Firstly, the need for care in the selection of LCD members. Secondly, the need to develop objective data on key farm physical attributes. Because such data had not previously been compiled, a geographic information system (GIS) was developed in order to characterise some of these features. Data included in the GIS were:

- a satellite image (Landsat 7 TM) which identified the location of all irrigation development determined by visual interpretation and on-screen digitisation;
- data on soils and landscapes from DLWC (derived from multi-attribute data for the Liverpool Plains);
- cadastral data from the Land Information Centre. These were printed on large-scale (A0) plots overlying satellite imagery. Irrigator members of the WMC were then able to mark (by hand) actual property boundaries for irrigators in their district. These were subsequently digitised using cadastral data as a basis for line placement; and
- DLWC groundwater bore locations with associated data on entitlement and usage.

Profitability of dryland and irrigated crops. Information on the profitability of irrigated and dryland crops was obtained from NSW Agriculture in the form of enterprise gross margins as part of its Farm Budget Handbook series (Scott 1999a,b). These are updated annually and published on the Department's Internet site (www.agric.nsw.gov.au). These budgets were used as a first approximation for representative farms. However, as they cover an entire region, they were amended for local practices and conditions existing in Zone 3. Such amendments can be undertaken as part of the LCD process.

Overhead costs. The Australian Bureau of Agricultural and Resource Economics (ABARE) undertakes an annual survey of a range of agricultural industries (ABARE 2001). This survey provides information on the financial characteristics and performance of broadacre and dairy farms across Australia. The survey also reports on a range of physical and social characteristics of farms. However, in normal circumstances there are insufficient sample points to provide reliable data on irrigation farms on a catchment basis.

Table 2. A typical irrigation farm in Zone 3 of the Namoi Valley.

Farm type and location	Irrigation system	Soil type	Water source	Property size	Land use
Cotton farm located on the Breeza Plains	Furrow with recirculation system	Black cracking clays	A mixture of groundwater and unregulated surface water supplies	Total area of 800 ha with 650 ha laid out to irrigation.	Cotton grown in rotation with wheat (70% of irrigated area), with beef cattle run on dryland areas

ABARE was commissioned in 1996–97 to undertake a more comprehensive survey of farms involving an additional 250 sample points in NSW. The purpose of the enhanced survey was to collect key production and financial data on irrigated agriculture across NSW catchments to support water-policy development and impact assessment. Some 402 irrigation farms were surveyed across NSW.

There were 77 farms sampled in the Barwon region, which covers 4 major catchments and 3 groundwater systems, including the Namoi. From this survey, ABARE extracted data for two small 'clusters' of irrigators in the case study area (the Namoi catchment). These data were used as the primary source of data on overhead costs. While ABARE also provide variable cost and income data as part of their survey, the NSW Agriculture Farm Budget Handbooks provide such data in a more useful format for analysing individual farm enterprise performance.

Because the 'clusters' for which ABARE overhead-cost data were supplied did not exactly match the representative farm descriptions, further data were obtained from local agricultural consultants to supplement the ABARE data. These data were then verified by local irrigators before being used in the representative farm model. NSW Agriculture has now widely adopted the approach of obtaining existing overhead-cost data that matches the farming system being analysed (from whatever reliable source is available—typically ABARE), then modifying it as part of the LCD process. Where there are no existing sources of such data, they can be collected at the LCD meeting or as part of a survey, census or case studies.

Farm data integration

With the collection of a range of data on farm characteristics outlined above, a method of summarising and integrating the data was required. A GIS was chosen to summarise physical data on the basis of its flexibility in representing data sets and its ability to visually convey physical attributes of farms to stakeholder groups and committee members. This has advantages from the perspective of both the analyst and stakeholders in terms of interpretation and communication. Some of the key physical data sets are illustrated in Figure 7.

When the various sources of data were overlaid in the GIS, an attribute table could be defined which showed the following details for each property in the study area:

- total farm size;
- soil type and landscape;
- area laid out to irrigation;
- area actually irrigated;
- area of on-farm irrigation storage;
- groundwater entitlement and use;
- surface water entitlement and use.

These data could be analysed for any combination of properties and hence could be used to provide physical data for selecting a representative farm. The approach has been used subsequently in other catchments to aid representative farm model development. There are, however, a number of drawbacks in the use of GIS. Firstly, where data sets do not currently exist, the time and cost of capturing them is often prohibitive. Secondly, such data sets have to be checked for accuracy (e.g. using the LCD group). Finally, data sets are captured at a variety of scales and are accurate only when used at that scale. Because GIS allows data to be presented at a paddock scale (or finer), such constraints can be overlooked, leading to spurious conclusions. Despite these concerns, we can conclude that GIS has the potential to be a powerful integration tool for the development of representative farm models, but more extensive use requires widespread refinement of core data sets available in NSW. The ability of GIS to not only integrate data sets, but also present them visually, has proved to be a powerful means for explaining to community groups the basis for selecting representative farm systems.

Farmer adjustment responses

The impact of proposed policy changes will, to a large extent, be governed by the way in which farmers respond to those changes. A range of farm responses might be taken to a reduction in groundwater availability including:

- reduce irrigated areas uniformly;
- reduce irrigated areas non-uniformly (e.g. based on returns per ML);
- maintain irrigated areas but reduce the application of water and suffer a yield loss;
- purchase additional water entitlement (either groundwater or surface water);
- sell remaining entitlement and focus on dryland activities; and
- improve water-use efficiency through improved irrigation technologies.

Figure 7. Use of GIS and satellite imagery for data analysis.

The response used in the actual evaluation of groundwater management options in Zone 3 used a combination of reducing irrigated areas (assuming some replacement with dryland crops) and lowering water usage on specific crops, with associated yield penalties. The latter were estimated from yield response functions determined in collaboration with research agronomists.

Some reflections on data collection techniques

No one data set is ideal or capable of supplying all the requirements of any economic analysis. Where available at an appropriate scale, existing secondary data on both physical and financial attributes will be the most cost-effective source of information. In our case study of groundwater use in the Namoi Valley, we relied extensively on a range of existing physical data (including climate, hydrology, soils and landscapes) as well as financial data (including income, variable and overhead costs for irrigators). However, as with most studies, these were not all available at the scale or level of detail necessary. In many cases, these data had to be amended to make them more relevant to the farming system being analysed, while in others, primary data were collected directly from irrigators.

Where primary data are collected from farmers, or existing secondary data amended, the data-collection technique needs to be sensitive not only to the problem being addressed, but also to the overall context of the study. Because of the community-based approach to implementing water reforms adopted in NSW, stakeholder involvement has been an important factor in ensuring community acceptance, not only of research results, but also of the policy outcomes derived from it. We found that approaches to data collection such as local consensus data techniques and case studies were a useful way of not only obtaining data, but also improving stakeholder involvement. In addition, these techniques provided a greater insight into farmer behaviour, such as responses to policy options, than more traditional census and survey techniques. LCD and case-study approaches cannot be used in isolation, however. Selection of farming system groups for analysis by LCD and case studies needs to be guided by, and results validated against, other data sources. Further, to be effective, LCD participants must be a cohesive group, preferably already established for another purpose, such as a Landcare or commodity discussion group. Where such groups do not exist, local extension staff should be used to help select participants.

Participants in both LCD and case-study analyses must also be representative of the farming system being analysed. The paucity of data at the farming system level led NSW Agriculture to explore some innovative approaches to defining such farming systems. Interpretation of Landsat TM satellite imagery proved to be a useful and cost-effective means of obtaining land-use information and is likely to be more widely used in the future as image resolution and computer capacities increase. The use of satellite imagery has not only helped with the specification of farming systems for analysis but also has provided a useful visual backdrop for illustrating a range of other physical data, such as property boundaries and areas irrigated. Unfortunately, Landsat images are less useful for analysing land-use involving smaller properties (<10 ha). In such instances, higher resolution satellite imagery or alternative approaches are required. These can be significantly more expensive.

A further innovative approach to data analysis has been the integration of biophysical data using GIS. This has provided a high quality, spatially accurate and integrated data set by which farming systems can be characterised. GIS data has, in turn, provided a good basis for undertaking more conventional data collection. However, where digital data sets have to be created as part of the project, GIS-based approaches can be both labour intensive and costly. This, along with data inaccuracies and scale limitations, constrains the potential usefulness of GIS until such times as digital data sets and associated data quality descriptions (metadata) are more routinely available. The greatest use of GIS has been for defining farming systems where there are few existing data on the nature of those systems. Otherwise, more conventional data-collection techniques such as survey, LCD or case study are likely to prove more cost effective.

Summary and Conclusions

The NSW Government is in the process of implementing a comprehensive water-reform agenda aimed at improving the health of NSW rivers, estuaries and groundwater based on a nationally agreed framework. The reform agenda involves fundamental changes to the way in which water is priced, allocated and traded. The impact of these reforms on extractive users may be more significant in NSW due to less-conservative approach taken to the allocation of water resources in the past.

The NSW Government has adopted a community-based approach to the implementation of water reforms. Community-based water management committees are required to consider the socioeconomic effects of proposed water management changes and need appropriate tools and information to help them in this process. The agricultural sector is one of the key stakeholder groups potentially affected by water reforms and NSW Agriculture has been working with WMCs to evaluate the agricultural trade-offs associated with policy change and to identify how these impacts will be distributed among the community.

The community-based approach to water reforms has important implications for the nature of studies undertaken and the sources of data used in them. These should be readily understandable by community representatives and seek to engage them in the process. A representative farm modelling approach has been adopted to quantifying the distributional impacts of water reform. A variety of modelling frameworks ranging from optimisation-based approaches to more simple budgeting techniques has been used across different catchments. Each technique has its own set of strengths and weaknesses in relation to the context of the analysis, the nature of the problem and the farming system under consideration.

While specific problems and modelling approaches have their own data requirements, an essential step in any analysis of agricultural impacts requires a basic understanding of irrigated farming systems. The paucity of data at the farming system level can pose a significant constraint to the development of these models. NSW Agriculture has used a range of data collection techniques from simple consensus data approaches through to more sophisticated remote sensing and GIS-based approaches to overcome these problems. NSW Agriculture has a large number of water management committees to service and a relatively small number of economists to undertake that work. As a result, the Department's has attempted to gather data in the most cost-effective means while maintaining acceptable rigour.

No one source of data or collection technique will provide all the information required. We have adopted an integrated approach to data collection which has combined a variety of secondary (census, survey, satellite imagery, GIS) and primary data collected from irrigators. Because of the community-based approach to implementing water reforms adopted in NSW, stakeholder involvement has been an important factor in ensuring community acceptance, not only of research results, but of the policy outcomes derived from it.

Approaches to data collection such as local consensus data techniques and case studies have been a useful way of not only obtaining data but also improving stakeholder involvement. In addition, these techniques provide a greater insight into farmer behaviour, such as responses to policy options, than more traditional census and survey techniques. LCD and case-study approaches cannot be used in isolation, however. Selection of farming system groups for analysis by LCD and case studies needs to be guided by, and results validated against, other data sources.

More innovative data sources and analysis techniques such as satellite imagery and GIS can be powerful tools for defining farming systems and guiding the collection of further physical and financial data. They can also be a very effective means of visually demonstrating to stakeholders the logic of farming systems groups. However, the use of readily available and inexpensive imagery is of limited use for examining small-scale agriculture, while GIS can be both labour intensive and costly. A decision to use either should be made on a case-by-case basis depending on the nature of the farming system and the availability, cost and accuracy of alternative data sets.

No data set is ideal or capable of supplying all the requirements of any study. The most suitable methodology and data collection technique will need to be sensitive, not only to the problem being addressed but the overall context of the study. An integrated approach is required. Some new data collection and integration techniques have been explored in this paper. These hold significant potential but the problems related to the availability of digital data sets need to be overcome before these approaches can be more widely used.

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