Water as an economic good in irrigated agriculture
Theory and practice

P.J.G.J. Hellegers
C.J. Perry

Project code 62525

August 2004

Report 3.04.12

Agricultural Economics Research Institute (LEI), The Hague

The Agricultural Economics Research Institute (LEI) is active in a wide array of research which can be classified into various domains. This report reflects research within the following domain:

- ☐ Statutory and service tasks
- ☐ Business development and competitive position
- ☑ Natural resources and the environment
- ☐ Land and economics
- ☐ Chains
- ☐ Policy
- ☐ Institutions, people and perceptions
- ☐ Models and data

Water as an economic good in irrigated agriculture: Theory and practice
Hellegers, P.J.G.J. and C.J. Perry
The Hague, Agricultural Economics Research Institute (LEI), 2004
Report 3.04.12; ISBN 90-5242-930-8; Price € 26 (including 6% VAT)
152 p., fig., tab., app.

This report describes the results of the Water Valuation and Pricing project, which aims to provide insight into the relevance of economics to typical problems found in irrigated agriculture. It first considers the theoretical basis for the use of economic instruments, then considers their usefulness in the context of five case studies of irrigated areas - in Egypt, India, Indonesia, Morocco and Ukraine. The case studies confirm that competition for scarce water and shortage of funds are widespread. The study provides insight into the current price paid for water, the cost of service provision, and the value to irrigators of the water they receive. The analysis shows that volumetric pricing is unlikely to be relevant to demand management because the price of water at which demand and supply would be balanced is so high as to substantially reduce farm incomes. This socio-political problem, plus the technical and administrative complexity of measuring and accounting for water, and the crucial distinction between water applied to the field and water consumed by the crop make water pricing an unsuitable approach to balancing supply and demand.

Orders:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: publicatie.lei@wur.nl

Information:
Phone: 31.70.3358330
Fax: 31.70.3615624
E-mail: informatie.lei@wur.nl

Contents

Page

Preface 7

Summary 9

1. Introduction 11

2. The role of economics in irrigation water management 12
2.1 Introduction 12
2.2 The meaning of treating water in irrigated agriculture as an economic good 13
2.3 Analytical tools 14
2.4 Theoretical basis for the use of economic instruments 18
2.4.1 Description of economic instruments 19
2.4.2 Suitability of economic instruments 20
2.4.3 Preconditions 23
2.5 Water applied versus water consumed 25
2.6 Conclusions 27

3. Current situation in the five case study areas 29
3.1 Introduction 29
3.2 Issues arising in the case study areas 29
3.3 Overview of the price, costs and value of irrigation water in the case study areas 32
3.4 Conclusions 35

4. Role of economic instruments in the case study areas 36
4.1 Introduction 36
4.2 Usefulness of economic instruments 36
4.3 Reasons why market-pricing and tradable water rights are not widely applied 41
4.4 Conclusions 42

5. Conclusions 44
5.1 General conclusions 44
5.2 Research recommendations 45

References 47

Page

List of definitions and terms 49

List of abbreviations 51

About the authors 53

Appendices 55
A Location and data of study areas 55
B Framework used to derive returns to water 57
C Egypt - Kemry 63
D India - Haryana 75
D1 Overview of outcome of the spreadsheets 91
E Indonesia - Brantas River Basin 93
F Morocco - Tadla 115
F1 Overview of outcome of the spreadsheets 129
G Ukraine - Crimea 131
G1 Calculation of water charges in Dzhankoy 151

Preface

This report describes the results of the Water Valuation and Pricing (WVP) project. This project is one of the sixteen projects of the Water for Food and Ecosystems Progamme, which cover a wide range of activities in a variety of countries. The WVP project uses a selection of the other projects of the Water for Food and Ecosystems Progamme as case studies. The objective of this project is to provide insight into the relevance of economics to typical problems found in irrigated agriculture not only in theory, but also in practice.

It is funded by the Partners for Water Programme, a joint effort by all relevant Dutch ministries to strengthen the foreign activities of the Netherlands Government and private sector in the field of water management by combining knowledge, expertise and financial resources. Partners for Water was initiated early in 2000 and will run until the end of 2004.

The research is conducted in collaboration with the International Water Management Institute (IWMI) in Colombo and International Food and Policy Research Institute (IFPRI) in Washington. Appendix E, the Brantas Basin case, is mainly the work of Charles Rodgers of IFPRI. Claudia Ringler of IFPRI assisted in the finalisation of the Brantas Basin case. It has also been submitted as an IFPRI-EPTD discussion paper. Appendix D and F are part of the book Irrigation water pricing policy in context: exploring the gap between theory and practice (F. Molle, R. Barker and J. Berkoff (Eds.)). Jeremy Berkoff has revised Appendix D substantially. Appendix F the Tadla case is prepared in collaboration with HR Wallingford as part of their research on Water Charging in Irrigated Agriculture.

The authors are grateful for the support of Koen Roest and Jan Bouwhuis. The authors would also like to thank Salem Shouhan, R.K. Khatkar, Nawal El Haouari and Victor Popovich for the data collected for Egypt, India, Morocco and Ukraine respectively. They also appreciate the useful comments of Jos van Dam and Gerrit van Vuren on a draft version of Appendix D and Appendix F respectively. Finally they like to thank Gerbert Roerink and Stefan Pavlov for their useful contributions to Appendix G.

Prof. Dr L.C. Zachariasse
Director General LEI B.V.

Summary

Recent literature and the recommendations of international conferences highlight the problems of competition for scarce water and shortage of funds for maintenance of irrigation facilities. Treating water as an economic good - using economic instruments to encourage water savings and to generate revenues - apparently addresses both issues. Economics also provides tools to analyse the implications of allocation between uses and users, and users' response to alternative allocation procedures such as pricing, quotas, and markets.

This study first considers the theoretical basis for the use of economic instruments, then considers their usefulness in the context of five case studies of irrigated areas - in Egypt, India, Indonesia, Morocco and Ukraine. The case studies identify the issues faced in each area, confirming that competition for scarce water and shortage of funds are widespread. All except one of the study areas are water-short. Two of the study areas (India and Morocco) allocate surface water successfully through quotas, but face problems of uncontrolled and excessive groundwater use. In Ukraine demand for water is less than the available supply, as poorly maintained equipment deter farmers from irrigating.

Estimates are made of the current price paid for water, the cost of service provision, and the value to irrigators of the water they receive. The analysis confirms that the value of water to farmers is considerably higher - usually a multiple - of the cost of providing the service. Only three of the five study areas fully recover operation and maintenance costs.

In assessing the relevance and applicability of economic instruments - quotas, crop-based charges, water pricing, and markets - the distinction is made between water that is diverted and applied to the irrigated area, and water that is actually consumed by the crops. Where excess water is recovered elsewhere in the system through drainage reuse or groundwater pumping - and this is the case to some extent in each water-short study area - increasing the price of applied water may have little impact on consumption. Furthermore, the impact that volumetric pricing may have on demand will be limited if a quota system is in place.

The various economic instruments are evaluated for each of the study areas. It is concluded that volumetric pricing is unlikely to be relevant to demand management because the price of water at which demand and supply would be balanced is so high as to substantially reduce farm incomes. This socio-political problem, plus the technical and administrative complexity of measuring and accounting for water, and the crucial distinction between water applied to the field and water consumed by the crop make pricing an unsuitable approach to balancing supply and demand. Higher volumetric prices (to the degree they are feasible) will encourage more productive use. The issue is whether costs of implementation exceed productivity gains.

The objective of managing scarcity is most readily achieved through quotas - which also encourage farmers to seek the most productive use of water. However, in two of the study areas (Egypt and Indonesia) the implementation of quotas at the farm level is impossible with the typically available infrastructure - a point that applies to all rice systems.

Beyond quotas, tradable water rights offer additional gains through the potential for reallocation of water.

Simple crop- or area-based charging systems with low administrative costs and a high degree of transparency are most suited to achieving cost recovery objectives.

Economics provides the means of analysing the implications of misallocation of water and assessing the social and productivity implications of various ways of allocating water. Sophisticated instruments such as market-clearing pricing, volumetric charges and tradable water rights have limited applicability and a low priority in the case-study areas, which are probably typical of many developing country situations.

1. Introduction

There is a lack of insight into the strengths and limitations of economics to solve typical problems found in irrigated agriculture. Most projects of the Water for Food and Ecosystems Programme approach problems from a purely technical point of view, whereas it is not clear what role economics can play, and the linkages between economic and technical considerations.

The question is not whether water is an economic good or not (it certainly is), but rather the extent to which water allocation and use can be guided by market forces or requires some extra management to serve social objectives. Experiences from the case studies will be used in this study to clarify the often-dogmatic positions set out by the proponents of each perspective.

As there seems to be a gap between the role of economic instruments in theory and practice, not only the theoretical basis for the use of economic instruments will be studied here but also the usefulness of economic instruments in the context of five case studies of irrigated areas. A selection of the other projects of the Water for Food and Ecosystems Programme will be used as case studies to assess the applicability of economic instruments as a means to achieve water management objectives.

Through this project, insight will be gained into the price paid for water, the cost of water provision, and the value of irrigation water (as well as in the way to derive such returns to water). This provides insight into the viability of cost recovery and its impact on the profitability of irrigation. Insight into the profitability of irrigation is especially useful to support decisions in Crimea with respect to the rehabilitation of the irrigation system. Besides it helps policy makers to understand to what extent charging for water is helpful in practice, and what purposes it can serve (like cost-recovery and/or demand management).

Five case studies are selected, covering a range of problems with respect to competition for scarce water and shortage of funds. They are Kemry in Egypt, and Tadla in Morroco (both from the Irrigation Reform in North-Africa project), Haryana in India (of the Water Productivity project), Brantas Basin in Indonesia (a basin comparable to Citarum of the water-less-rice project), and Crimea in the Ukraine (of the Watermuk project).

In Chapter 2 of this report the theoretical basis for the application of economic instruments to typical problems found in irrigation water management - effective resource management and sustainable financial management - is studied. Some 'real world' experiences - issues faced - in the five case studies of irrigated areas are described in Chapter 3. The usefulness of economic instruments in the context of the five case study areas is assessed in Chapter 4. General conclusions are drawn and some research recommendations are made in Chapter 5.

2. The role of economics in irrigation water management

'An economist might be described as someone who doesn't see anything special about water.' (Tregarthen, 1983).

2.1 Introduction

The last decade has seen a growing interest in the importance of treating water as an economic good, as highlighted at several conferences. The Second World Water Forum (The Hague, March 2000) stressed that decisions on water allocation among competing uses require a better analysis of the value of water (SWWF, 2000). The International Conference on Water and the Environment (Dublin, January 1992) emphasised that failure to recognise the value of water has led to environmentally damaging uses of the resource (ICWE, 1992). The recommendations of international conferences confront the problems of competition for scarce water and shortage of funds for maintenance of irrigation facilities.

That water generally is an economic good follows directly from Robbins' (1952) definition of economics as 'the science, which studies human behaviour as a relationship between ends and scarce means which have alternative uses'. Water meets these requirements: it serves a multiplicity of ends (ranging from drinking and bathing, through irrigation, navigation, recreation, and environmental use, to waste dilution and disposal), and thus satisfies the condition of 'alternative uses', and the widely observed competition between sectors (productive and environmental) confirms that water is frequently scarce.

Recent literature and recommendations of international conferences confront the problems of competition for scarce water and shortage of funds for maintenance of irrigation facilities. The current rationale for treating water as an economic good - using economic instruments to encourage water savings and to generate revenues - apparently addresses problems with *effective resource management* as well as problems with *sustainable financial management*. Problems with effective resource management arise when water is scarce, misallocated, wasted or when there is a lack of incentives to improve the productivity of water. For instance when too much water is being used, aquifers are falling, rivers drying up, and wetlands shrinking. Problems with sustainable financial management arise when too little is being paid by the users, water supply agencies are under-funded and maintenance inadequate, which leads to poor system management and in return a low willingness to pay.

Economic literature has extensively discussed the meaning of treating water as an economic good (Briscoe, 1996, Perry et al., 1997 and Rogers et al., 2002). At the operational and even the policy level, however, there is still confusion about the potential role of economics in improving water management in general, and irrigation management in particular. When water is scarce and allocation among competing uses is necessary, economics provides us with two contributions: *analytical tools* that help predict and interpret the implications of water allocation between uses and users, and users' response to alternative allocation procedures, and *economic instruments* to encourage water savings and to generate revenues. In this chapter the potential role of each contribution to improved management is discussed.

Analytical tools can be used to support decisions about the appropriate allocation of water among competing users, and to provide insight into users' response to alternative allocation procedures such as price increases, quotas, and markets. Examples of such trade-off analyses are cost-benefit analysis, cost-effectiveness analysis, rate of return and net present value computations, and optimal control theory. Such analyses require insight into the average and marginal *costs* of supplying water and/or in the average and marginal *benefits* of using water.

Economic instruments provide incentives to influence behaviour - for example reducing demand, encouraging some preferred uses, or providing a market to allow the transfer of water from one use to another. The most obvious and widely studied economic instrument is *volumetric water charges* - assigning a charge to water and making payment for water a direct function of the quantity supplied. Sometimes this is extended to include the idea that the charge should be determined in the 'market clearing' sense so that the available resource is fully allocated, and allocated to its highest-value uses, referred to here as *market-pricing*. 'Fully allocated' in this context means allocating the sustainable yield of a particular source - over-exploitation of aquifers is unsustainable; drying up of wetlands or estuaries is environmentally damaging. *Volumetric water charges* are only *one* of the instruments that can be used to meet such objectives. Other economic instruments like tradable water rights and subsidies can also be used - as well as instruments that are also 'economic' in nature though different in their design, application and impact from the market approach. These include rationing or quotas, crop-based and area-based charges.

The structure of this chapter is as follows. In Section 2.2 the meaning of treating 'water in irrigated agriculture as an economic good' will be reviewed. In Section 2.3 the potential role of analytical tools in water management will be discussed. Special attention is paid to causes of market failure. The difference between the price, cost and value of water will be explained. In Section 2.4 the theoretical basis for the use of economic instruments will be discussed. In Section 2.5 the importance of the distinction between water applied and consumed will be illustrated. Finally, in Section 2.6 conclusions are drawn.

2.2 The meaning of treating water in irrigated agriculture as an economic good

As noted above, water is frequently an *economic* good because there is insufficient water available to meet competing demands. A *free* good, by comparison, is available in abundance for all current uses - for example, air. Water in an undeveloped perennially flowing river also approximates to a free good. Being *free* does not imply that the good is not valuable, but rather that it is not scarce. A number of other definitions of 'goods' from economics also illuminate various characteristics of water in different situations. In economic terms, goods are primarily defined by two characteristics - whether consumption by one person precludes consumption by another (if so, consumption is referred to as 'rival' consumption[1]), and whether access to the good can be controlled ('excludability'). The four possible combinations - with examples including from the water resources sector, are:

- *Private* goods are rival in consumption and easily excludable - apples, water rights;
- *Public* goods are non-rival in consumption and non-excludable - a lighthouse, civil defence, navigation on the high seas;
- *Near-public* goods are non-rival in consumption, but easily excludable - libraries, run-of-the-river hydro-power generation;
- *Common property* goods are rival and non-excludable - a river or aquifer that is significantly developed.

Interest in treating water as an economic good relates to the situations where water is scarce - and hence use is *rival*. Economics also provides the concept of *opportunity costs* - the value of the alternative foregone by use of a resource. For example, supposing we have purchased a ticket to a show for $ 10. If tickets are scarce it may be possible to sell the ticket for $ 15. If we attend the show, the *financial* cost of that choice is the original $ 10, but the *opportunity* cost is $ 15. It demonstrates the role of a market in determining more accurately the value of the ticket than the 'administered' price. All these issues relate to the notion of treating water as an economic good: water is an economic good if it is scarce, which implies that consumption is rival; common property issues are likely to be prevalent in managing water; opportunity costs must be considered in devising ways to allocate water; and markets may be able to contribute to management if water can be treated as a private, tradable good.

Treating water as an economic good means that, when water is scarce, allocation decisions should take account of benefits to each user (or uses), the costs of service provision, and foregone benefits to users (or uses) who do not have access to water. Such considerations should improve the allocation of water on the basis of trade-offs that have financial, economic, socio-economic and/or environmental implications for those directly concerned, as well as society more generally. Treating water as an economic good is about making the right choices, and not necessarily about setting the appropriate price for water (Savenije, 2000). Nor does it mean that water should be allocated by market-prices (Perry et al., 1997).

2.3 Analytical tools

The apparent simplicity of 'evaluating tradeoffs' should not be underestimated because of all the issues of valuation summarised above. Consider two water-constrained farmers, one of whom grows flowers that generate $ 1/m^3 while the other grows rice, generating $ 0.1/m^3. The more productive farmer will be happy to pay the less productive farmer (say) $ 0.2/m^3 to buy some or all of his water, and this will allow both farmers to be better off. This simple financial trade-off demonstrates how an economic instrument - tradable enti-

[1] The linkage between water and economics is confirmed, perhaps, by the origin of the word 'rival' - from the Latin word for river.

tlements for water - and a market can lead to a better outcome for all. But a closer examination of the situation might reveal the following:

- That the rice produced by the low-productivity farmer was helping keep the price of basic foodstuffs down for the poor;
- That the water used by both farmers was pumped from a river where the estuary was being damaged by insufficient flows;
- That the high productivity farmer was using pesticides that harmed fish and the incomes of fishermen;
- That the high-productivity farmer came from a disadvantaged group (poor female head of household, say).

These hypothetical possibilities raise issues of low consumer prices, food security, income distribution, environmental damage, third-party impacts and social issues. The simple outcome of the market does not result in a distribution, or aggregate consumption, that meets legitimate concerns about environmental, social and other impacts of their activities of a particular allocation of water.

Such problems are cases of *market failure* - when a market left to itself does not allocate resources appropriately, as judged by society. Economists have identified four main sorts or causes of market failure.[1]

- the abuse of market power, where a single buyer or seller can exert significant influence over prices or output;
- externalities - when the market does not take into account the impact of an economic activity on outsiders;
- provision of public goods, such as national defence;
- where there is incomplete or asymmetric information or uncertainty.

Several of these types of market failure occur in water resources management. The abuse of market power occurs when the wealthy owner of a large well is able to dominate exploitation of an aquifer, with shallower wells rendered useless. Similarly, farmers at the head end of an irrigation system may have dominance in the use of the resource.

Externalities are extremely common: diversion of water from a river may impact on fisheries, navigation, recreation, or the environment. Each withdrawal from an aquifer that causes a fall in the water table imposes additional pumping costs on other users, yet a farmer does not benefit from refraining from pumping - the 'commons' problem.

Water management is also subject to severe issues of uncertainty due to the nature of the hydrological cycle. There is also uncertainty with respect to agricultural crop markets.

Some of these failures may be addressed through the appropriate definition of rights: Coase (1960) has pointed out that once rights are defined (be it water rights or pollution rights), if an efficient market exists then an (economically) efficient allocation of rights will ultimately be arrived at. This important insight deals well with the 'commons' issue: if users are assigned rights to exploit an aquifer up to (but not beyond) its sustainable yield, then the aquifer is protected and the more productive users will buy rights from the less productive users to the benefit of all. Trading 'rights' will result in an efficient final alloca-

[1] www.economist.com/research/Economics.

tion - provided the prices prevailing in the market are based on conditions consistent with the objective being sought. For example, where market prices are distorted by taxes and subsidies (as in the European Union's agricultural policy) the allocation and prices of resources that will result from trading in water rights will be different from what would prevail in a 'free' market. This is not to suggest that allocations and prices determined under 'free' market conditions are necessarily 'right'.

Society often prefers to allocate water in ways that are inconsistent with the free market - reasons include: providing water services to the poor; allocating water to develop irrigation in backward areas; irrigating parks/gardens in cities for aesthetic reasons; and ensuring that sufficient water is released to estuaries/wetlands to protect the environment.

The very long list of 'adjustments' to free market outcomes that arise in the case of water management suggests one reason why market solutions are rarely found in the water sector. Even the common assertion that privatised domestic water utilities are an example of the role of markets in water is generally based on the misconception that market forces are significantly shaping the allocation of water among sectors - whereas to the extent market forces apply at all (and it is difficult to have competing services) they actually apply to the costs of treatment, delivery and collection of waste - not to allocation of water.

Some have suggested that when the price of water reflects its true costs, markets will ensure that the resource will be put to its most valuable uses (Rogers et al., 2002; Rogers et al. 1998). However, such 'true costs' are often difficult to interpret practically. In a case study based on an Indian river where not all domestic needs were met, opportunity cost of water in such uses was estimated at \$ 0.59/m^3 (Bhatia, 2000). This implies irrigation charges of several thousand dollars per hectare in areas where agricultural incomes are a few hundred dollars per hectare. The apparent paradox results from the fact that transfer of a rather small amount of water out of agriculture would rapidly bring the value of water down to agricultural opportunity cost levels. This is not to suggest that transfers should not be made, but rather to point to the need to understand the shape of the value curve, and not to base prices on extreme point estimates.

In fact, the water market is not homogeneous (Savenije and v/d Zaag, forthcoming):

- Irrigators need a lot of water, but have a low ability to pay;
- Urban and industrial users need little amounts, but have a high ability to pay;
- Urban and industrial users need water of high quality and high reliability; and
- Irrigators may accept water of lower quality and lower reliability.

So, the water needed by each sector is not completely substitutable.

In fact, water is also a *social good* whose availability will serve the greater benefit of society as a whole - and thus as many possible values as there are perspectives on what is 'right' for society. Water used for irrigation can for instance be a powerful means of reducing food costs to poor people; irrigated agriculture may also support economic development in rural areas, providing jobs and supporting agro-food industries in areas, which should otherwise become depopulated (OECD, 2002). This is not just an issue in predominantly agricultural, developing countries: studies by the US Department of Agriculture (Gollehon, 1999) document the direct and multiplier effects of transfer of water from rural to urban uses in the USA. Such impacts explain why the government sometimes subsidises those uses of water that have a high social value, but low ability to pay (Hartwick and Olewiler, 1998). Social concerns may require subsidies, but need to be transparent. It is therefore a challenge to identify the right balance between water treated as an economic good and water treated as a social good - a balance that is generally only achieved through political processes.

Some past failures in water resources management are attributable to the fact that water has been provided free (or almost free) of charge. Access to clean water is often seen as a basic right of all human beings (ICWE, 1992), because it is often considered as too vital to humans to be left to the economic forces of profit-maximisation (Gibbons, 1986). Besides, many societies believe that water has cultural and religious values (FAO, 1994) and should not be paid for. In the absence of other controls on its use, this will lead to misuse, low economic and social returns, water being allocated to low-value uses, and no incentives to treat water as scarce.

Treating and analysing water as an economic good helps us *identify* these issues, but does not prescribe solutions - rather giving guidance as to *where* solutions may lie, and the extent to which economic tools can support such solutions.

Many of the issues identified above will be resolved in ways that reflect specific local circumstances, customs and beliefs - the outcome of that process will define how much water can sustainably be allocated to irrigation use, and the remainder of this section considers how economic analysis can assist in making best use of such resources.

An economic approach helps define prices, costs and values of water. The *price* is the volumetric price of water - how much extra the irrigator pays per unit of water received. Often, with crop-based or area-based systems, the marginal price is zero (that is, the charge is 'per hectare' with no precise linkage between volume received and total payment) and once the farmer has decided to irrigate there will be no marginal incentive to save water. The *costs* of water are those costs incurred by the supplier in the provision of water, i.e. includes operation, maintenance and replacement costs and capital costs in the form of amortisation charges. The *value* of water is the net incremental production resulting from use of water by the current user, and the *opportunity* cost is the maximum amount an alternative user would be willing to pay. In each case, the numeraire will be 'X'/m^3 and analysts must be confident that the definition of 'X' - which in a simple financial analysis will be dollars - correctly reflects any other social or environmental dimensions. We must also distinguish between average and marginal values, as set out in the following example.

Suppose an irrigating agency has the right to pump as much water as it wishes from a river. The fixed costs are \$ 100,000/yr, plus a variable cost of \$ 0.01/m^3 pumped (Table 2.1) We see from these data that the marginal cost of water is always \$ 0.01/m^3, implying that the agency makes a positive return at any price above this figure. If 5,000,000 m^3/yr is supplied, the price must be set at three times the marginal cost in order to break even.

Now consider the farmers: suppose for simplicity we have 1,000 farmers each with 1 ha, and each hectare consumes (when fully irrigated) 5,000 m^3/yr. The maximum possible demand is thus 5,000,000 m^3/yr. If we further assume that the value of water to farmers is \$ 0.05/m^3 we see that the farmers can pay an irrigation charge of \$ 0.03/m^3, leaving them a profit and the agency will be fully funded. In fact the agency would be seeking additional customers because it has the capacity to pump much more water, which if sold at any price in excess of \$ 0.01/m^3 would provide the agency with additional profits.

Table 2.1 Cost of water as a function of volume supplied

Supply (m^3)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Average Cost ($/$m^3$)	Marginal Cost ($/$m^3$)
0	100,000	0	100,000	-	0.01
500,000	100,000	5,000	105,000	0.21	0.01
1,000,000	100,000	10,000	110,000	0.11	0.01
5,000,000	100,000	50,000	150,000	0.03	0.01
10,000,000	100,000	100,000	200,000	0.02	0.01

With the same set of data in respect of costs and potential income to farmers it is useful to consider a drought situation where only 1,000,000 m^3 of water are available. At this level of delivery we see that the agency needs to charge $ 0.11/m^3 which is more than twice the value of the water to the users: if the agency tries to recover its costs demand will be zero and the agency will be worse off (due to fixed cost) than if it sold the water for the best price it can get knowing that this will mean a loss!

Now consider the situation where farmers can actually use water in a variety of ways - on water productive crops (vegetables, cotton, etc) or water intensive crops (sugar cane), and where some farmers are simply better than others. If water is an economic good (i.e. it is scarce), we would like to ensure that supply and demand for water are brought into equilibrium, to reallocate water from the less productive to the more productive users (assuming this does not conflict with income distribution or poverty objectives), to increase production per unit of water consumed by the individual user and to avoid wasteful use. Simultaneous with these objectives, we also want the agency to be financially sustainable (i.e. to recover costs either full or partial and have a stable income). What economic instruments can assist in this; how do they work and what effects do they have?

2.4 Theoretical basis for the use of economic instruments

The following range of instruments can be employed to meet water management policy objectives: rationing, volumetric water charges, tradable water rights, crop-based charges, area-based charges, and cropping pattern controls. Each is 'economic' in the sense that they impact upon farmer behaviour through his desire to maximise the returns to his assets, though some, clearly, are more market-based. Rationing is considered as an economic instrument in this study, since it induces an economic response. As the nature of economic instruments is rather complex, a mutually understood terminology is required. Each instruments is therefore first of all described below. Secondly, the suitability of economic instruments to achieve the water management objectives listed above is assessed. Thirdly, the preconditions for effectiveness of the instruments are set out.

2.4.1 Description of economic instruments

Rationing is allocation of water to specific uses or users on a quantitative basis. The amount of water supplied to the user is his *ration* or *quota*. The quantity may be entirely fixed (for example, 1,000 m^3 per month), or according to a formula (for example a fraction of the available supply, such as 10 % of river flow, or 10 % of reservoir storage as of a certain date). The user whose entitlement is so specified may be an individual farmer, a town, or an environmental use. Although rationing systems can be complex - with entitlements and priorities varying according to hydrological circumstances - rationing in general is a very transparent system of allocating scarce supplies. If water demand hardly responds to higher water charges (i.e. if the price elasticity of water demand is low), rationing will be more effective in constraining demand than water charges. If increases in demand for water are expected, then a rationing is also preferred as it constrains usage at the same level.

Volumetric water charging occurs when the charge is based on the actual quantity of water delivered. Volumetric pricing can be applied even if the total quantity of water available to the user is set as a quota. If the farmer can demand any amount of water at the agreed price, the system is based on *market-pricing*. Volumetric water charges always provide an incentive to reduce usage. The effectiveness of such incentives depends on the elasticity of demand. As long as the net incremental productivity of water exceeds the water price, demand will increase. The threshold at which demand is significantly affected by volumetric charges depends among others on the productivity of water, set of production strategies, proportion of land devoted to permanently irrigated crops, and irrigation technology (Garrido, 1999 and De Fraiture and Perry, 2002). In consequence, finding the market-price at which supply and demand are equal poses a difficult challenge.

An alternative approach to volumetric water charges, which allows stability of demand to be encouraged through the pricing system is to *vary the volumetric price depending on the total demand* (often referred to as block-rate pricing). Thus if the expected availability of water is 5,000 m^3/ha, the first 4,000 m^3 may be supplied at a low volumetric charge; the next 1,000 m^3/ha at a much higher rate, and additional water at a rate that is much higher still. This system provides incentives to limit demand, while targeting the desired consumption level accurately for reasons of sustainability and/or social equity. When the charge for the extra amounts is much higher, it is likely that all use will concentrate around the basic availability.

Tradable water rights allow users with an assigned water quota to sell the quota to another user (or buy additional quotas from others). Tradable water rights combine the clarity and certainty of a quantity-based rationing system with the possibility of reallocation of rights through market mechanisms The total volume of rights is limited and therefore usage is constrained to availability. The marketability of rights encourages users to reduce low value usage and sell surplus water. At the broader scale, since the water rights assigned within a basin are fixed, there is no actual reduction or increase in overall demand through trading, just a reallocation from lower to higher value uses. Only if an outside agency buys rights and 'retires' them is there a reduction in demand.

Crop-based charges are fixed per hectare depending on the crop type. Often, rates are higher for more water-consuming crops (sugar cane, for example), and may also be kept artificially low for the staple foods of the poor - thus combining social objectives with the economic objective of 'signalling' the higher resource cost of water intensive crops.

Area-based charges are based directly on the size of the irrigated area and have no linkage either to the volume of water supplied or any indirect measure of consumption.

Controlled cropping means that the government constrains the allowable cropping pattern - either fully, by specifying the proportion of land to be occupied by each and every crop, or partially, by limiting or banning specific crops. Such controls take account of the assumed water requirement of each crop type to ensure that water demand is within feasible limits. It may be argued that this form of intervention is essentially 'command and control' rather than an economic tool, but the approach is included for completeness.

2.4.2 Suitability of economic instruments

The tools and objectives can be presented as a matrix, see Table 2.2 The relevance of each tool to each objective - represented by a cell in the matrix - is discussed below. Before discussing the instruments, it is important to realise that the objectives sought, and instruments available, must be evaluated in the context of a highly dynamic situation: water availability varies from year to year; crop prices rise and fall - absolutely and relatively; new varieties, pest attacks, and the many other uncertainties of agriculture mean that a policy and an instrument that look entirely reasonable in the 'average' year will have sharply different results in every other year. Stability of outcomes - that the supply and demand for water are balanced each year, and that revenue streams for essential operation and maintenance are broadly adequate every year - are essential characteristics of a viable system.

Table 2.2 Shows whether the objective can be achieved by the tool (Yes, means that it is suitable)

Objectives / Tool	Rationing	Volumetric water charges	Tradable water rights	Crop-based charge	Area-based charge	Controlled cropping
Effective resource management:						
- Balance supply and demand	Yes	Possibly	Yes	No	No	Yes
- Reallocate to alternative uses	No	Yes	Yes	No	No	No
- Increase productivity of water consumed	Yes	Yes	Yes	Possibly	No	Yes
- Avoid wasteful use	Yes	Yes	Yes	No	No	No
Sustainable financial management:						
- Cost recovery	No	Possibly	No	Yes	Yes	No
- Stable income to the agency	No	No	No	No	Yes	No

Rationing will not raise any money to cover the costs. Rationing can be applied to meet any specified overall level of usage (where supply equals demand). It can be arranged to assign usage in ways that may be socially desirable (for example, by giving higher priority to certain uses in conditions of scarcity, or assigning a ration to an environmental use). It is effective in controlling usage to a specified level by means of a limit on use for each farm, but it will not provide any incentive to reduce water use beyond this limit. Farmers who previously received excess water will realise the opportunity cost of water. This may lead to those formerly growing a crop with a high value of production per hectare, like sugar cane, to switch to a crop with a higher value of production per unit of water consumed - a desirable outcome in a water-scarce situation. To this extent, usage will be reduced in the most efficient way, but at a wider scale there is no transfer of use from the less productive to more productive users or sectors. Rationing is transparent, and allows an open debate about the level of ration assigned to particular uses and priorities among users.

Volumetric water charges give clear incentives to reduce water consumption, provided the charges are significant in relation to the value of water and the cost of management. In Figure 2.1, the current price Pc does not reflect the marginal value MV of water use, i.e. the current price is not on the demand curve (as the quantity is often limited by rationing), see Figure 2.1. A considerable increase in the price of water is needed to balance supply and demand. The market clearing price Pe will lead to a fall in income (and may therefore not be desirable). A positive marginal price of water can give incentives to reduce water demand, but transaction costs may be high.

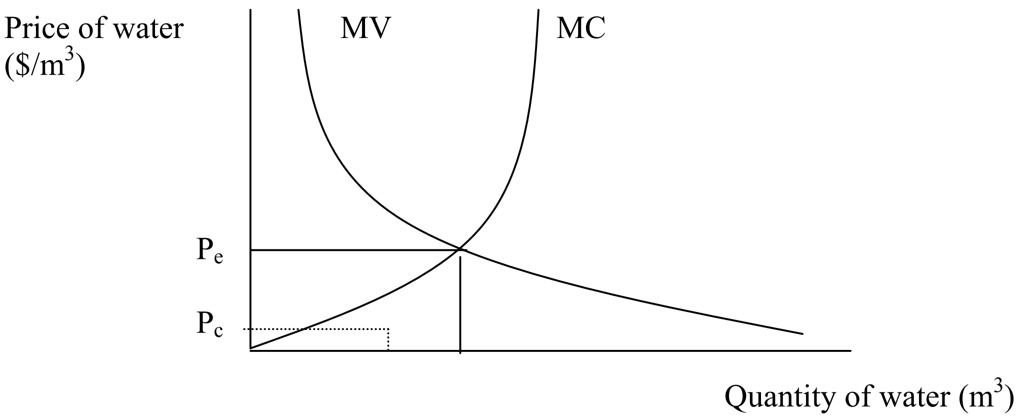

Figure 2.1 The current price Pc and market clearing -economically efficient- price Pe of water

Charges not only affect demand, but may also encourage increased supply if it is possible (with new investment) to develop new resources.

Volumetric charges are poorly suited to cost recovery: in a drought, where the agency has limited water to sell, revenues will fall proportionately; in a year of high rainfall, demand for irrigation water will be limited, again leading to revenue shortfalls. Thus ensuring appropriate revenue levels where volumetric charging is applied also requires an additional 'per hectare' charge. Volumetric water charges require means of accurate volumetric measurement - so that supplier and user agree on the service that has been provided. Most existing irrigation systems do not allow accurate measurement. Further, since the effectiveness of volumetric charging requires that the individual farmer choose the quantity of water per hectare he wants independently from the quantity supplied to his neighbour, the intensity of management (and control infrastructure) is very high. If there are a large number of small users, the transaction costs of such a system will be high.

It is worth reviewing the common arguments made in *support* of introducing volumetric water charges, which fall primarily into two broad categories. The first basic argument proposes that when water is free, or under-priced, it is likely to be used inefficiently. Volumetric water charges provide an incentive to improve the efficiency of allocation of water in specific uses, such as irrigation, and to improve the overall allocative efficiency of water across sectors. The second basic argument proposes that water charges are necessarily linked to the ability of water management agencies to provide water, and to the quality of the water service provided, through the mechanism of routine (O&M) and capital expenditures in water resources. If collected fees are insufficient to ensure the proper maintenance of water storage and distribution systems, performance declines, and water use becomes increasingly inefficient for physical reasons. Water users may thus achieve a 'false economy' in which they pay little or nothing for their water directly, but as a consequence are subject to declining income resulting from deteriorating water service. Embedded in the second argument is an appeal to fairness: beneficiaries of investments in water resources infrastructure should pay their fair share of the capital and recurrent costs. This is often formalised as the 'user pays principle.' An assumption common to both arguments is that in the absence of an appropriate system of incentives, water will be used inefficiently. In the cost recovery argument, the inefficiency reflects the divergence between what society invests in the provision of water resources and what is recovered. In the marginal value form of the argument, inefficiency results from the misallocation of water to uses that do not reflect the appropriate opportunity cost.

Arguments *against* the introduction of water charges typically are based on social welfare concerns, on assertions of access to water as a basic human right and on various interpretations of prior appropriations doctrine. Volumetric water charges are not widely applied in water policy for a number of reasons. There might be market imperfections. Also, there might be an uncertain relationship between charges and extraction. Moreover, they are less suitable when emergency problems arise or the government wants to ban a certain extractor. Further, they may not be widely applied because they are politically sensitive or new. Finally transaction costs may be high relative to the size of efficiency gains.

Tradable water rights require first that allocations of water by user are defined, monitorable and enforceable. This step is a major challenge in most water short countries. Once established, tradable water rights that can be bought either on a short-term (seasonal) or long-term (permanent) basis. The price of such rights is usually market-based - that is, there is no interference by government to affect prices - with a component to cover the administrative costs of the trading system (which must also include analysis of third-party impacts). As such, payments made in this market are unrelated to cost recovery for the provision of the irrigation service itself. In any case, since the trade in water rights will be irregular, depending on hydrological and agricultural market conditions, and prices will similarly vary unpredictably, the income stream from such a system is not well suited to cost recovery objectives. Since the rights available for use of trade will be defined in relation to the known supply of water, tradable water rights must control demand at a certain level, even if new parties enter the market. Like rationing, tradable water rights provide incentives to concentrate usage on the most profitable crops, and since water that is not used can be sold, this traded water will be reassigned to more productive users, thus achieving an additional productivity benefit. Tradable water rights serve to encourage productive water use at the level of the individual farmer and between farmers (or non-farm users).

Crop-based charges generate a relatively predictable revenue stream to recover costs, especially where irrigation supplements rainfall, because the revenues are independent of the volume of water applied. Since the farmer is left free to select his cropping pattern, there is no particular reason to expect supply and demand to be equalised. It will not reallocate water to more productive users or sectors. It will provide incentives to economise water usage provided the level of the crop-based charge is sufficiently high to switch from high to low water consuming crops. It will increase production per unit of water consumed by the individual user if the level of the crop-based charge is sufficiently high to compensate losses due to a switch in crops.

Area-based charges generate a predictable revenue stream that can recover costs. Such a system will not usually ensure a balance between supply and demand. If the water available is almost always adequate to meet demand - so that all the farmers in a scheme are served equally well, this system can directly allocate the desired level of service charge over the area served, and provide a simple and effective means of charging. By definition, there are no incentives in such a scheme to save water or encourage productive use beyond the incentive that every farmer has to farm profitably.

Controlled cropping will not raise predictable revenues to recover costs. The allowed cropping pattern can be defined and enforced by the irrigating agency or some other part of Government in such a way that may bring supply and demand into equilibrium. The system does not give an incentive to reduce water consumption or reallocation between users. It will increase production per unit of water consumed by enforcing a switch in crops.

In sum, none of the instruments meets all of the common management objectives, so that a combination of instruments will usually be required. Instruments can be combined in such a way that they reinforce or complement each other. Although these policy mixes are complex and difficult to develop, the most successful experiences show that they are viable and perhaps the only way to achieve multiple-objective reforms. This brings OECD (2002) to conclude that a mixture of instruments can be fruitful. In selecting which instruments to use, it is important to bear in mind the issues raised earlier in this section - the need for predictability and stability of outcome, combined with ease of implementation.

2.4.3 Preconditions

The suitability and applicability of economic instruments depends not only on the water management objectives, but also on a variety of pre-conditions being in place. Required preconditions for the introduction of specific economic instruments are discussed here. The preconditions identified (which are a minimum set, often with additional difficulties in particular scenarios) are summarised in Table 2.3.

The instruments are put in order of complexity of implementation. The first instrument discussed is the most complex one, with the highest transaction costs.

Table 2.3 Shows which of the preconditions required for implementation of the various tools have to be met

Tool / Preconditions	Tradable water rights	Volumetric water charges	Rationing	Crop-based charge	Controlled cropping	Area-based charge
- Volumetric measurement at farm level	X	X				
- Disaggregated supply at farm level a)	X	X				
- Defined water rights	X		X			
- A legal framework to charge for water		X				

a) Disaggregated supply means that adjacent farms can be supplied at different rates and schedules.

Tradable water rights have failed to develop in many areas, since many requirements have to be met. Well-defined water rights are hard to establish[1], since water is not a homogeneous product. Besides, tradable water rights require means of accurate volumetric measurement and disaggregated supply at farm level.

A precondition for *volumetric water charges* is accurate volumetric measurement of water delivery and disaggregated supply at farm level. The irrigation system might, however, be designed in such a way that volumetric measurement is not possible. Transaction costs will be high when there are a large number of small users. Besides, it will only give incentives to reduce on water use, when you are in the price elastic part of the demand curve. Moreover a legal framework to charge for water is required.

Rationing can be implemented in two ways. In a simple form, where all farms receive the same quantity and schedule of water deliveries per hectare, in which case no measurement or control at the individual farm level is required (Warabandi is the prime example of this). It can also be implemented in a more complex basis, where seasonal accounts of deliveries at the farm level are kept, against a total seasonal allocation (as in the Murray Darling basin). The latter requires that supply can be disaggregated at farm level.

Crop-based charges are relatively simple to administer. The transaction costs are low, since no volumetric measurement or definition of rights is required. It will only give incentives to reduce the irrigated acreage of some crops when the charge is sufficiently high to change the relative profitability between crops.

Controlled cropping is also relatively simple to administer against low transaction costs (although some monitoring is required as farmers may pursue unauthorised crops).

Area-based charging is the simplest system to put in place, requiring no measurements of any sort except the farm area, which remains constant. It functions like a land tax.

Some more general criteria for the review of the suitability of instruments are economic efficiency, effectiveness (to what extent do policies meet objectives), administrative feasibility (how easy is it to implement, monitor and enforce policies), social equity and cultural, religious and political acceptability (Hellegers and Van Ierland, 2003).

[1] For example, codification of water rights in the Murray Darling basin took 30 years - in areas where water resources management was already orderly, farmers were educated, rules were followed and the broad basis for allocation rules was already in place (Don Blackmore, personal communication).

2.5 Water applied versus water consumed

In assessing the relevance and applicability of economic instruments it is important to make a distinction between water that is diverted or applied to the irrigated area, and water that is actually consumed by the crops. Water that is applied to the field is only partly consumed by the crop (see Figure 2.2). The other part returns to the system (recoverable losses) or flows to sinks like saline aquifers and the sea (non-recoverable losses). At field level (for example, from the farmer's point of view) flows to drains as well as flows to sinks are both real losses, whereas at watershed level only the flows to sinks are a real loss. As flows to sinks remove water from the hydrological cycle, they can also be considered as consumptive use. Many common uses of water are essentially non-consumptive: diverted water is almost entirely returned to the system after use (flushing toilets, bathing, cooking).

Applied (A)	Non-consumptive use	Non-recoverable losses
		Recoverable losses
	Consumptive use (C)	

Figure 2.2 Water consumption versus application at field level

Where excess water applied is recovered through groundwater recharge or re-use of drainage water the concept of 'losses' is misleading. Only the non-recovered part of applied irrigation water is really lost (as it does not return to the system). Reducing the part of water applied that is 'lost' is only useful when it concerns non-recoverable losses (or when it is expensive to re-use it due to deteriorating quality or required energy to lift water). The main resource management objective is to minimise non-recoverable losses, whereas the main financial objective is to minimise all losses as it costs money to treat and apply water.

The consumed fraction of water applied to the field (C/A) can be increased by improved irrigation technologies, which is mainly interesting for resource management objectives in the case of non-recoverable losses.

The water productivity (Yield/C; mass of product compared to mass of water consumed) can be increased by better management, like systems of rice intensification (SRI). SRI will, however, only save water delivered to the field instead of water consumed. Only half of water applied on paddy is evapotranspirated, the rest goes to seepage and percolation and for management practices such as land preparation. In most cases, excess applications of water (beyond what is directly needed for evapotranspiration) are recovered and reused by farmers lower in the system, so that SRI will not solve the resource imbalance. Nevertheless SRI is useful to keep water 'high' in the system (so that the choices as to where and when to release water are maximised) and can ameliorate the impact of reduced allocations to specific areas

It is consumptive use that (a) produces the benefit for the farmer and (b) produces the resource imbalance. The response of a farmer who faces a higher charge for water applied (and volumetric pricing is invariably based on water applied, not water consumed) will be to try to reduce water applied and maintain consumption by means of improved irrigation technologies. This will not change the resource deficit in areas where losses are recovered elsewhere in the system through drainage re-use or groundwater pumping (Perry, 2003b).

There is a lack of insight into the responds of irrigation water demand to a higher water charge (price elasticity of water demand), but it is clear that at low price ranges the part of water applied A that is really consumed C is lower than at high price ranges (as improved irrigation technologies are used in high price ranges). Increasing the price will give an incentive to reduce the part of water applied that is lost. It is likely that the slope of the water-consumed line is steeper than the slope of the water-applied line, which means that water-consumed is less responsive (lower price elasticity of water demand) to a change in the water price (see Figure 2.3). This means that volumetric water charges will mainly reduce losses instead of consumption, which will not save water (assuming that losses can be re-used). If consumption hardly responds to a higher water charges, rationing will be more effective in constraining consumption than water charges - though again, the farmer will seek to maximise the consumption of the water that he is allowed to divert.

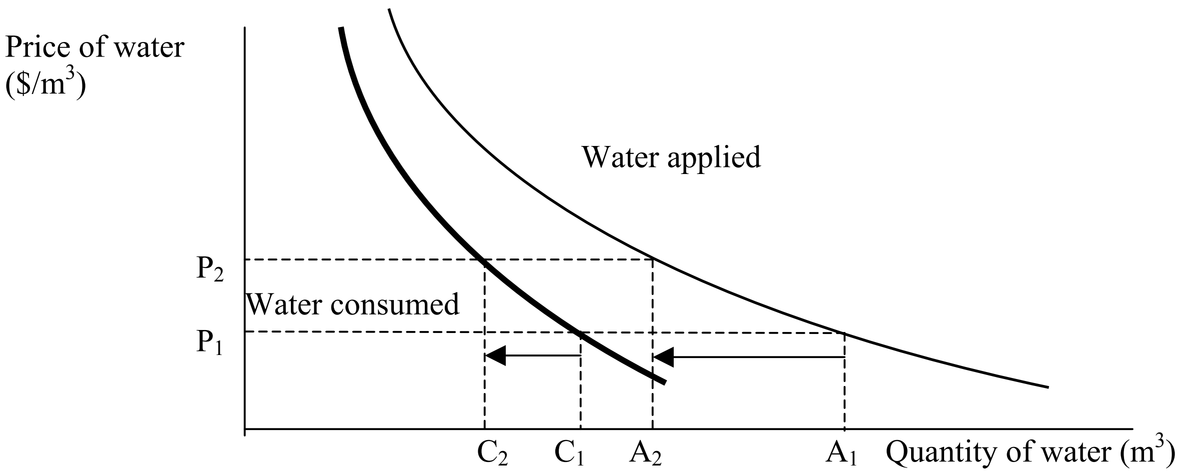

Figure 2.3 Responds of water applied A and water consumed C to a higher water charge

It is often argued that higher water charges will encourage adoption of modern irrigation technologies and consequently reduce demand for water. This raises an interesting issue: Economic theory tells us that as long as an input is scarce, demand for that input will tend to increase as its productivity increases (more output per unit input). Improved irrigation technologies increase the productivity of water, and increase the profit derived from water consumed (assuming that the increase in output will not reduce the output price). This means that an increase in the price of diverted water may result, -through the mechanism of induced investment in 'better' technology, a higher consumed fraction, and higher productivity of diverted water-, in an increase in water consumed. Figure 2.4 shows that higher water charges may induce an increase in water consumed (assuming it is possible to expand the irrigated area), although it may induce indeed a decrease in water applied. It generates a vicious circle, which requires even higher charges to reduce water consumed.

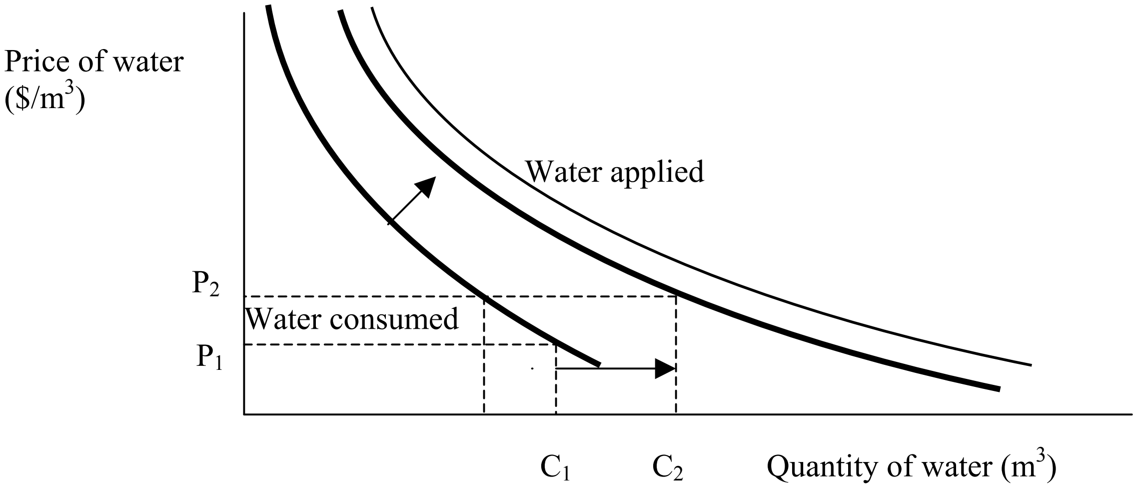

Figure 2.4 Modern technologies may induce an increase in water consumed

This study has identified the potential impact of interventions that increase the productivity of water on the demand for water, which is an extension of existing work in this field. It becomes clear that it is not likely that high levels of farm management practices and technical control, like a system of rice intensification that increases the productivity of water, will reduce water consumed. It does, therefore not seem to be a suitable instrument to reallocate water to alternative uses outside agriculture,- but such technologies can ameliorate the impact of reduced allocations to specific areas

2.6 Conclusions

The meaning of treating water as an 'economic good' relates primarily to recognising that when water is scarce, allocation decisions should take account of foregone benefits to potential users as well as benefits to actual users, and the costs of service provision,- thus recognizing that it has opportunity costs and should not just be appropriated through uncontrolled market mechanisms or by the rich or powerful or historic users. Such considerations help in evaluating the allocation of water among potential users on the basis of trade-offs that have financial, economic, socio-economic and/or environmental implications for those directly concerned, as well as society more generally.

Economics provides valuable analytical tools and concepts for understanding the nature of water and how its use can be controlled and influenced. Economic analysis is also useful in tracing through the implications of various options for allocating scarce water resources and including criteria beyond simple profit and loss. Complex criteria - such as income distribution, environmental concerns, or inter-generational equity - make it more difficult to define a single numeraire; deriving weights and values for any non-financial criteria is difficult; incorporating more than one will often lead to enormous complexity of evaluation.

Volumetric water charges are a potential instrument to reduce demand and recover costs, but are also often politically sensitive, complex to administer, and require sophisticated infrastructure. It became clear that volumetric charges for water applied will mainly reduce water applied instead of water consumed, which will not change the resource deficit in areas where most losses are recovered. Furthermore, a relatively high charge is required to induce significant reductions in demand. If such a price is politically or socially unacceptable, additional controls will be required to ensure that demand is controlled - raising the question of whether the complexity of water pricing is worthwhile if additional controls are in fact the basis for controlling demand.

It is also clear that it is not likely that high levels of farm management practices and technical control, like a SRI that increase the productivity of water, will reduce water consumed (as demand for an input tends to increase as its productivity increases).

Finally, since irrigation may reduce food costs and support development in rural areas social concerns lead governments to sometimes subsidise those uses of water that have a high social value, but low ability to pay. It is therefore a challenge to identify the right balance between water treated as an economic and social good. Especially for irrigated agriculture, which faces high opportunity costs if there is competition from urban use, while the ability to pay for irrigation water is often very low.

3. Current situation in the five case study areas

3.1 Introduction

In Chapter 2 broad conclusions were drawn from a theoretical viewpoint regarding the relevance of economics to typical problems found in irrigation projects. The main experiences from the case studies are reviewed here to see whether the expectations that were put forward in Chapter 2 are confirmed.

In selecting the case studies, the aim was to cover a range of experiences with differing degrees of economic development, varying degrees of water scarcity, and differing agricultural and water management practices. The cases were selected from the other subprojects funded under the Dutch Water for Food and Ecosystems Programme.

The selected areas were Kemry in Egypt and Tadla in Morroco (both from the Irrigation Reform in North-Africa project), Haryana in India (of the Water Productivity project), Brantas Basin in Indonesia (a basin comparable to Citarum of the water-less-rice project) and Crimea in the Ukraine (of the Watermuk project). The location and some socio-economic data of each country are presented in Appendix A. Detailed results for each case study are presented in Appendix C-G. In each case the objective is to:

- assess the current situation:
    - problems with resource management and sustainable financial management;
    - policy objectives;
    - existing policy instruments;
    - irrigation infrastructure and institutions;
- estimate the price, cost and value of water; and
- recommend policy instruments to address the problems and required preconditions.

The particular problems arising in the various case study areas and existing policy objectives and policy instruments are summarised in Section 3.2. The price, costs and value of water in each case study area are compared in Section 3.3 and insight is provided into the methodology used. Recommended policy instruments are described in Chapter 4.

3.2 Issues arising in the case study areas

Problems with effective resource management, sustainable financial management and sustainable environmental management in the case study areas are described below and summarised in Table 3.1. Existing policy instruments are described for each study area.

Problems with *effective resource management* often arise when water is scarce. Common symptoms are disputes over water, wasteful use by some while others have inadequate supplies, lack of clarity about priorities, and lack of incentives to save water or improve productivity. Often these problems emerge over time as demand increases from sustainable to unsustainable levels. For example, Egypt will have to deal with canal water scarcity in the future given the plans to expand production, through increasing the cropping intensity in the 'old lands'; and expansion of the irrigated area in 'new lands'. In fresh groundwater areas in Haryana and Tadla there are falling groundwater tables, as surface water supplies are limited and the aquifer is now overdrawn. Excessive water use has to be avoided in saline groundwater areas, like in Haryana and Tadla because water percolating to the aquifer is effectively 'lost' to further productive use, and contributes to the rising water table and waterlogging. In the Brantas Basin agricultural use is excessive and must be reduced (reallocated) to meet urban demand. Society will benefit from interventions that reallocate water to more productive uses.

Financial sustainability is often an issue - either because charges are too low, or are not collected. Low charges or the failure to collect a large percentage of billed charges generate low revenues. Governments are increasingly unwilling to bridge the financial gap between low recoveries and the needs for proper maintenance and consequently poor maintenance of irrigation systems is widespread, which leads to poor system management and a low willingness to pay - completing a vicious circle. The limited degree of cost recovery is a problem in Kemry, Brantas and Crimea. Where revenues are insufficient, either the government must bridge the gap (Egypt) or the irrigation scheme will deteriorate (Ukraine). The Ukraine case is unusual - and perhaps a warning - in that current prepayments for water delivery and lack of maintenance have induced a substantial decline in demand, which in turn requires still higher prices to recover costs from the smaller 'sales' based. Costs of irrigation will even increase further in Crimea, as modernisation of the irrigation system is required. Establishing an effective legal and administrative framework that ensures accurate billing and high levels of fee collection is therefore a priority task, greatly complicated by the fact that further increases in price may not, in current technical and economic circumstances, be feasible.

Finally, the *environment is often damaged* by the way water is managed - through water-logging and salinisation, for example. In Haryana and Tadla there are waterlogging problems due to unnecessary recharge as a result of irrigation during times when it is not needed. To achieve environmental sustainability, it is important to address these negative externalities.

Table 3.1 Overview of issues in the case study areas indicated by X

Study area Objectives	Kemry	Haryana saline	Haryana fresh	Brantas	Tadla	Crimea
Effective resource management:						
-Balance supply and demand	X		X a)		X a)	
-Reallocate to alternative uses				X		
-Increase productivity of water consumed		X			X	
Sustainable financial management	X			X		X
Sustainable environmental management		X	X		X	

a) Supply and demand of canal water are balanced, but supply and demand of groundwater are not balanced.

The challenge that faces managers of Egypt's irrigation system is how to deal with scarcity. Increasing demand from other sectors, more intensive irrigation in the 'old lands', and expansion of the irrigated area in 'new lands' has effectively 'created' scarcity. The Irrigation Improvement Project was originally seen as a means of saving water, but experience shows that water is not saved - indeed consumption may often be increased. Traditionally farmers draw collectively from a below ground channel. Under the Irrigation Improvement Project farmers take water from a common source by means of pumping into an above ground channel, so that the quantity pumped can be measured. This is, however, often not working. The present attempt at volumetric allocation of water in Kemry is not feasible to balance supply and demand in an equitable fashion - as maintenance of credible records of deliveries at the field level is impossible. Any attempt to introduce water measurement has enormous implications on how the system is operated, the infrastructure needed and the formalisation of rights. The system in Egypt is designed to deliver full crop requirements. Although Egypt's field irrigation efficiency is thought to be inefficient - only 40% of applied water is actually used by the crop - an increase in the local efficiency is of little benefit, as losses in one location are generally recovered elsewhere. Besides some outflow to the Mediterranean is necessary to meet flushing requirements of the system. Hence improvements in local 'efficiency' will not save water at the basin level.

Haryana is one of India's major irrigating states, with some 3 million hectares under surface irrigation. Rice, wheat and cotton are the major crops. Water is scarce - the design cropping intensity was only 60% - and the irrigation system is designed to divide the limited surface water supplies equitably over the command area following a rigid rotational schedule. All irrigation is by furrow irrigation. The dominant instrument currently in effect in Haryana is rationing of scarce surface water. The warabandi system allocates water to all irrigators in proportion to their land holding - in fact water rights rest with the land, not the owner of the land and cannot be sold separately. The system leads to a defined and generally predictable allocation of surface water among users. Market-pricing or tradable water rights are difficult to introduce in this context because the proportional division of water is intrinsic to the legal basis for allocating water and the infrastructure, which comprises tens of thousands of kilometers of channel and at least ten thousand structures, all of which would need reconstruction. The existing crop-based charge is appropriate, as it recovers costs and provides some incentives to allocate water to water-efficient crops with low transaction costs - though the primary incentive for productive allocation of water at the farm level is the limited availability. Where the groundwater is fresh the area is also served by private wells and the water table is falling; in saline groundwater areas the water table is rising and waterlogging is a problem - both are difficult problems to manage.

The design of the irrigation system in the Brantas, by which water within a tertiary block flows naturally from one field to another lower-laying field in the terrace irrigation system, makes volumetric measurement -and consequently volumetric water charges- impossible. Crop-based charges are currently used to recover costs There is an increasing urban demand for water, which has to be met by diverting water away from irrigated farmland. Currently a de facto quota system is in place. Farmers in the Brantas basin, for example, know that most of the irrigated crops in the second dry season are considered unauthorised, that is, they will not necessarily receive additional water to maintain their crops. A quota system can work, as farmers know in advance how much water they can expect, and thus can adapt their cropping plans accordingly. However, farmers are currently not compensated if they receive less water as they do not have a license and are not paying for bulk-water deliveries, contrary to other use sectors. This was particularly visible in the 2003 drought when farmers in the Citarum basin had to watch water passing by in full canals sent to Jakarta - they had no recourse for the imposed quota/rationing system, apart from social unrest/protests.

Tadla in Morocco is one of the largest irrigation schemes in the country - almost 100,000 ha of surface irrigation. Tadla is already using very suitable instruments - rationing canal water combined with volumetric charging - to recover O&M costs and discourage wasteful use. A considerable increase in the price of canal water would be needed to balance supply and demand, but seems socially undesirable as it imposes a substantial burden on farm economic welfare and might trigger an increase in (unsustainable) groundwater usage. Rationing of canal water use is therefore likely to remain the dominant instrument. Recently the government proposed to reduce irrigation charges by giving farmers a greater management role, by means of Participatory Irrigation Management. This does not seem to be successful in Tadla, as financial incentives (remissions of charges) when farmers take over tasks are limited. Tadla is, however, not a representative irrigation project. To overcome constraints of canal water availability and flexibility many farmers have invested in private tube wells, while (as in Haryana) policy to control groundwater use has not received a lot of attention.

Crimea in Ukraine faces the quite different problem of low demand for water. Water availability exceeds demand mainly due to poorly maintained and malfunctioning irrigation equipment. The lack of farmer funds for maintenance is the result of uncertain markets for agricultural products and transitional problems. The limited degree of cost recovery is a problem. Costs will even increase further, as modernisation of the irrigation system is required. A decline in demand in return requires still higher charges to recover costs from the smaller 'sales' based. It is therefore important to increase demand. Under current policy in Crimea it is very bureaucratic and expensive to obtain water rights and there is still hardly any participation of farmers in irrigation management. Policy should change from 'maintaining and preserving the traditional way of irrigated agriculture' towards 'stimulation of irrigation for all water-users' in a financially and environmentally sustainable way.

3.3 Overview of the price, costs and value of irrigation water in the case study areas

The price and costs of water can in principle be observed directly or derived from financial data, including project documents. The value of water, by contrast, must be estimated, since it is seldom the case that farmers bid for water under competitive market conditions involving other economic sectors. Here, we take the value of irrigation water as the net income received by the farmer per unit of water applied. In this study we do not attempt to derive marginal returns to water (the extra income that a farmer would derive from an additional cubic meter of water). In general, under conditions of water scarcity, average value is a reasonable proxy for marginal value because farmers are trying to maximise the return to the scarce resource.

The framework set out in Appendix B is used to assess returns to water at farm level in Egypt, Morocco and India. The approach provides a simple framework for collecting data related to farm incomes, water and labour use. The spreadsheet then automatically computes indicative returns to land, labour and water. By subtracting the cost of other production factors from the gross production value, the net value added per unit water can be calculated. It is important to note that such returns are difficult to compute precisely in the absence of a major modelling exercise. First, the precise technical coefficients (yield/ha, water use, etc.) will vary across farms and by year. Second, some inputs are difficult to capture accurately because they are not monetised (like family labour), or may be subject to distortions due to taxes or subsidies. Third, a precise analysis of the impacts of economic instruments would require identification of marginal as well as average returns, because these are the values that induce responses

It is important to note in this respect that the conclusions are based in part on information about annual O&M costs, farm input prices, crop yields and market values - all of which vary from season to season - but the sample data collected for this project serve to highlight underlying issues and indicate conclusions that are generally valid.

To facilitate comparison, prices, costs and values are expressed per cubic meter, even though the charge may be levied on a per hectare basis. Thus if a farmer uses 5000m^3/ha and pays an area-based charges of $ 10/ha, the implicit volumetric price is $ 10/5000/m^3. Farmers in Tadla and Crimea pay a relatively high price for water, see Table 3.2.

Only operation and maintenance (O&M) costs are presented in Table 3.2. Capital costs are not considered as they should be based on replacement costs, which are often hard to derive. In the Brantas there is a big difference between O&M costs ($ 0.001/m^3) and full costs ($ 0.006/m^3), whereas in Tadla there is a small difference between O&M costs ($ 0.017/m^3) and full costs ($ 0.02/m^3). The reason for this is the fact that Tadla is an old system, which requires more maintenance, but was (in today's prices) cheap at the time of construction. Costs of irrigation are low in the Brantas as water flows naturally from one field to another. Costs of operating the system in Haryana are also low, as the warabandi system is particularly simple and managed at a high level in the system.

Table 3.2 Price paid by irrigators (i.e. present fee), O&M costs and value of water ($/m^3)

	Price paid		O&M Costs		Value of water
Kemry	0.0004	<	0.010	<	0.08
Haryana	0.0005	<	0.0013	<	0.04
Tadla	0.0200	>	0.017	<	0.10
Brantas	0.0002	<	0.001	<	0.04
Crimea	0.0020	<	0.012	<	0.11

By comparing the price paid by irrigators and O&M costs[1] of water insight can be provided into recovery of costs. The data excludes the cost of pumping by farmers, as the purpose of this study is to assess the costs incurred by the state in relation to payments made by farmers. In Tadla O&M costs are fully covered by charges imposed on irrigators. In Haryana costs are also fully covered, but not entirely by irrigators. In Haryana only 33% of overall costs are allocated to irrigation, and the rest to the higher value uses, which receive priority of supply in times of scarcity, and a more continuous and predefined service. The

[1] The price should actually be compared to full costs *to farmers' borders*, which is not done for simplicity.

crop-based charge ($ 2/ha/yr for 4,000m^3, equivalent to $ 0.0005/m^3) covers the allocated cost share. In Kemry, Brantas and Crimea, O&M costs are more than 5 times higher than implicit volumetric prices.

By comparing the O&M costs[1] and the value insight can be provided into the profitability of irrigation. The value of water varies between $ 0.04-0.11/m^3 and exceeds the O&M costs - which means that irrigation is on average profitable - in all regions. Unambiguous statements about the profitability of irrigation are, however, hard to make since values of water vary not only among crops, but also among years due to fluctuations in crop prices and yields due to stochastic weather influences. Costs vary in Crimea not only among districts, but also within districts as costs of lifting water increase stepwise and exceed, at a certain altitude, returns to water. Energy prices are critical in this respect.

Table 3.2 shows that average returns to water are higher than the O&M costs, which in turn is higher than the implicit volumetric price of water. This means that the average returns to water are substantially higher than the volumetric price of water. Even if the price increases to the full cost of O&M, the effect on demand would be limited because returns to water are still higher. However, such a price increase will clearly have significant adverse effects on farm income. This conclusion is identical to that reached by Perry in 1995.

The price of groundwater is often higher than the price of canal water - it averages for instance $ 0.005/m^3 in Haryana and $ 0.032/m^3 in Tadla - but is still considerably lower than average returns to water. As long as this is the case, the incentive is to use more water. This explains why groundwater tables continue to fall in fresh groundwater areas.

When analysing a system of irrigation charges it is important to make a distinction between the level of the charges (that is the total charge paid) and the structure of the charges (fixed charges unrelated to volume delivered; volume related charges such as crop-based charges; charges entirely dependant on the volume delivered; or a combination of fixed and variable charges). Depending on the structure of charges, the marginal price may be zero, low or high - which determines the incentive for a farmers to demand more or less water. The overall level of charges determines the profit a farmer derives from irrigating. Sometimes the level of charges on irrigators may be less than the total cost attributable to irrigation. Provided the balance is recovered from other sources - a direct subsidy from government, or income from non-irrigation water sector activities - financial sustainability of the irrigation system is achieved.

The allocation of costs to irrigation is complicated by many factors: (i) irrigation provides additional food for society in general, lowering prices and increasing food security; (ii) irrigation (and agriculture generally) operates in a global economy where prices are severely distorted by the policies in the US and EU that generate large volumes of subsidised exports; (iii) irrigation underpins social development in areas that may otherwise be backward. Determining appropriate levels of irrigation charge is thus a complex and often contentious issue - what is clear is that it is in no-one's interest to construct expensive, productive facilities and allow these to deteriorate for the lack of political will to fund maintenance.

---

[1] The value of water should actually be compared to full costs (to society) of irrigation - including foregone benefits in alternative uses, environmental impacts, etc., which is not done for simplicity.

Usually only the private benefits are quantified and not the social benefits from irrigation, whereas the government may attach values to water allocations that contribute to improved income distribution or that encourage rural development, or reduce food costs for consumers. Public intervention is usually required to avoid under-provision of such contributions and encouragements, and such interventions can be considered as a kind of public good.

3.4 Conclusions

Experiences from the case studies confirm that competition for scarce water and shortage of funds are widespread. All except one (Crimea) of the study areas are water-short. It becomes clear that although there is often scarcity of canal water, it is managed in a sustainable way (mainly by means of rationing policies). Two of the study areas (Haryana and Tadla) allocate canal water successfully through quotas, but face problems of excessive groundwater use.

It is notable how frequently the reality or possibility of groundwater depletion comes up. Policies for sustainable groundwater management are, however, often missing. In general it is desirable to maintain the water table between an upper extreme - above which crop yields are affected - and a lower extreme, which provides adequate potential storage in the aquifer to capture surplus rainfall, but is not so deep as to make pumping excessively expensive. Although it is recognised that control of imbalances is a matter of concern for the long-term viability of irrigated agriculture, it is difficult to address in practice.

If pricing is to be effective, a number of conditions must be met: (i) the amount of water delivered must be a matter of agreement between the farmer and delivering agency; (ii) the volume actually delivered must be quantified; (iii) the payment for delivery must be a direct function of the actual volume delivered; and (iv) the price must be sufficient to induce a response in demand (Perry, 2000).

The possibilities of meeting the first three criteria are very limited in the case of large surface irrigation systems, but the criteria may be met in the context of groundwater irrigation - where the number of farmers served is relatively small, control over the delivery is precise, and payment arrangements can easily be related to delivery volume. Price will, however, only have a significant impact on demand when the price is significant in relation to the benefit. Costs of pumping and delivering groundwater are usually substantially below the value of groundwater in irrigated agriculture (which is why over-abstraction from aquifers is widely observed). An increase in the price to reduce demand would probably be politically unacceptable. Much more research is therefore needed into practical means of establishing and enforcing groundwater rights.

In the case studies, estimates are made of the current price paid for water, the cost of service provision, and the value to irrigators of the water they receive. The analysis confirms that the value of water to farmers is considerably higher - usually a multiple - of the cost of providing the service. Only two (Haryana and Tadla) of the five study areas fully recover O&M costs.

4. Role of economic instruments in the case study areas

'Dogmatic posturing by proponents that judge water as private good versus proponents that judge water as an public good is a waste of intellectual talent.'
(Perry et al., 1997).

4.1 Introduction

The theoretical basis for the use of economic instruments is set out in Chapter 2, whereas the usefulness of economic instruments in the context of the five case studies of irrigated areas will be considered in this Chapter. This assesses whether the complexity of using market-pricing and tradable water rights to address priority problems in the case study areas is worthwhile, i.e. whether beneficial impacts offset implementation problems.

In section 4.2 economic instruments have been proposed on the basis of their relevance to meet policy objectives in the study areas taking account of required preconditions. In Section 4.3 the gap between the role of market-pricing and tradable water rights in theory and practice is explored by being critical of theory and hence justifying reality.

4.2 Usefulness of economic instruments

Important preconditions for the introduction of economic instruments, discussed in Section 2.4, are absent in most study areas, see Table 4.1 The Irrigation System is designed for scarcity management in Haryana and Tadla, but not in Kemry. Disaggregate supply is only successfully applied in Tadla. The Irrigation Improvement Projects in Kemry is designed to provide disaggregate and measurable supply to individual farmers - though not always working. In Crimea disaggregated supply is only possible at the collective farm level, but will be a problem at the much smaller scale of future privatised farms - especially in the context of deteriorating infrastructure.

Table 4.1 Preconditions. Yes indicates 'met'. No indicates 'not met'

Study area	Kemry	Haryana	Brantas	Tadla	Crimea
Volumetric measurement	Yes b)	No	No	Yes	Yes c)
Disaggregated supply	Yes b)	No	No	Yes	Yes c)
Defined water rights	No	Yes a)	No	Yes a)	Yes
Legal framework to charge	No	No	Yes	Yes	Yes

a) Yes seasonal distribution of canal water as proportion of available supply, but not for groundwater; b) Yes IIP is designed to provide disaggregate supply, but is not always working; c) Yes but only to collective farms

Rationing of canal water is used successfully in two study areas where water is scarce (in Haryana and Tadla, there are quotas for canal water depending on availability, but there are no quotas for groundwater). In Haryana quotas are a simple proportion of available supply - not as a volume of water. In Tadla quotas are quantified by farm and measured close to the point of delivery. In both cases the limitation of water use provides and incentive for users to avoid waste and irrigate crops with a high return to water. It provides a transparent means of allocating water, ensuring that consumption of water is controlled, and making farmers individually appreciate that water is scarce.

Although rationing is a relatively simple instrument, it is not simple to introduce and operate. It requires infrastructure to allow division of water among users - which was part of the original design concept in Haryana and Tadla. Success requires that irrigators respect the rights of others. Where irrigators are accustomed to getting 'enough' water, such a change may be difficult to implement even if the infrastructure is capable of delivering the assigned quota. Delivering transparently measurable quotas is not possible in Brantas or in Egypt (though it is conceivably possible in the Irrigation Improvement Project areas).

Other non-economic issues may also be important if rationing is introduced - for example in Egypt, rationing water would (positively) encourage farmers to avoid crops such as sugar cane, but would (negatively) encourage deficit irrigation, upsetting the salt balance. In the Brantas basin, rice is grown in a contiguous area which shrinks or grows depending upon water availability. If the water allocation is reduced through rationing it is impossible to ration at the farm level (irrigation is largely field to field) so that the impact of the reduced supply falls entirely on tail-end farmers.

Volumetric Water Charges are used in Morocco. Farmers are assigned a water quota for the season, but only pay for the proportion of the quota they actually use. Typically since water is scarce farmers utilise the entire quota - the incentive to reduce water use and pay lower charges is lower than the value the farmer expects from using the water. Volumetric charging requires sophisticated infrastructure allowing measurement of water delivered to individual farms. This is not possible in any of the other study areas, and is expensive to introduce.

Market-pricing is the objective of irrigation charging in Crimea, but the situation is still in a state of flux. During the Soviet era, water was supplied to large co-operative farms, measured at the point of delivery, and charged at an agreed rate. Since the collapse of the Soviet Union, the co-operative farms have nominally been divided into small private farms, to be managed as individual enterprises, with water charged volumetrically to individual farms. The irrigation system is often incapable to deliver to individual farms (in some areas many farms are served by a single large centre-pivot units, capable of supplying the entire area or nothing). Measuring water deliveries in such a situation is not feasible. The uncertain environment compounds the problem of low demand for water, but at the present price of water demand is less than available supply.

The only other case study area that could introduce market-pricing (as a means to balance supply and demand) is Tadla. Elsewhere it is technically infeasible - water use cannot be measured, and supply cannot be differentiated between farms -, but in Tadla incomes would be significantly reduced if market-pricing alone was used to balance supply and demand.

Tradable Water Rights are not used in any of the case study areas (except for minor local trading of irrigation turns in Haryana). Only in Tadla and Haryana are water rights reasonably well specified - a precondition for tradable water rights requiring a very substantial investment of effort). In Haryana, significant tradable water rights could only be applied at the level of a group of farms sharing a common outlet, requiring agreement among farmers.

In the other study areas the scope for tradable water rights is unclear but probably limited; in Brantas land could be purchased by the government and the associated 'normal' water use reassigned to the water-short cities (an issue would be whether the water reassigned should be the water applied to the purchased land or the water consumed - the ratio is likely to be large). In Egypt, similarly, land could be purchased and the associated water use transferred - again requiring a collective agreement from a group of farmers sharing a common outlet.

While tradable water rights provide the most promising basis for achieving real increases in the productivity of water through the application of economic instruments the preconditions are significant - definition of rights, monitoring of water use in relation to rights, and most significantly the ability to identify and compensate for third-party impacts. If a use in one location was resulting in aquifer recharge, maintenance of natural vegetation, or in-stream flows on which other uses depended, then transfer of such usage requires determination of the extent to which part of the original usage must remain (or be otherwise compensated).

Crop-based charges are the most common in the study areas - found in Kemry, Haryana and Brantas. The approach is popular because it is relatively simple to administer, provides a reasonable proxy measure of water or overall benefit received from the irrigation service, and a reasonably stable income to the irrigation agency. Although charges may be higher for crops that use more water, there is no evidence that the differences in charge are sufficient to significantly affect cropping patterns. The primary purpose is to generate funds to cover cost.

Area-based charges are not used in any of the study areas. Such charges have two particular advantages: exceptional ease of collection - no measurement of water, irrigated area or crop type is required, and the income to the agency is certain. Area-based charges have a potential role in two of the study areas - in Tadla, where revenues currently vary due to availability of water, while costs of operation and maintenance are (relatively but not absolutely) fixed. The other study area where area-based charges have a potential role is Ukraine (see below).

In fresh groundwater areas in Haryana and Tadla development of groundwater within surface irrigation systems is a serious threat to the viability of the aquifer. Whether the water table is stable depends on the balance between additions from percolation losses and abstractions through pumping. Formalisation of groundwater rights, and the definition of sustainable quotas, are crucial to achieving the balance that resource sustainability requires. An alternative approach, which is equitable and relatively easy to enforce, involves systematic monitoring of groundwater levels, and the decision prior to the irrigation season, as to whether groundwater irrigation in the seasons will be unrestricted, or banned (Perry, 2000).

An overview of existing and recommended economic instruments is provided in Table 4.2. The recommended instruments to achieve the main objectives are summarised below.

Table 4.2 Existing and recommended economic instruments

	Kemry	Haryana	Brantas	Tadla	Crimea
Existing instrument	Crop-based charge	Rationing canal water Crop-based charge	Crop-based charge	Rationing canal water Volumetric charges	Volumetric charges
Recommended instrument	Control water-intensive crops Retire irrigated land	Reliable water supply in saline areas and Define groundwater rights in fresh areas	New farm management practices	Define groundwater rights	Area-based and crop-based charge to recover energy costs

In Egypt water will be diverted away from long-developed areas with high productivity to newer less productive areas. This should be done in a fashion that minimises negative impact on the highly productive system. It is therefore recommended to limit particular water-intensive crops and the irrigation intensity. There are three options: 1) controls can be placed and enforced on crops such as sugar cane and rice, although controls on rice are currently failing; 2) if water scarcity becomes a significant issue due to expansion of the irrigated area, then either seasonal canal closures can be implemented to prevent any irrigation in the hotter months; or 3) areas can be rotationally closed on a seasonal or annual basis, so that available supply is shared equitably among all users, in a transparent and systematic fashion. Although yields may be lower in the 'new land', returns to water may be higher as often niche crops like early melons are grown, which are sold against high crop prices. Unlike in Haryana and Tadla, where the system is designed to deliver limited supplies, the system in Egypt was designed and managed to deliver full crop water requirements. That is why deficit irrigation - a delivery policy of applying less than full requirement - is not proposed. As pricing for water is a sensitive issue, it is recommended to keep the crop-based charge in place.

Haryana in India is performing well: cost recovery objectives are being met, scarcity of canal water is being managed transparently and equitably, and productivity is high. However, the physical infrastructure that underpins these objectives limits the prospects for more flexible irrigation scheduling and hence the possibility to use pricing as a demand management tool. It is recommend to relate water supplies precisely to crop demand in the saline groundwater areas -where any excess is lost and contributes to waterlogging-, while delivering any poorly timed, excess water to fresh groundwater areas - where it can be recovered. However achieving this would be hard to promote through economic means. Improved irrigation technology can also reduce the negative impact of water losses on the environment. Rights for groundwater use are inadequately specified in Haryana. A landowner is entitled to pump and utilise water lying beneath his holding - leading to the classic 'tragedy of the commons' problem. It is therefore recommended to control groundwater use in fresh groundwater areas. The existing crop-based charge for canal water is appropriate, as it recovers costs and provides some incentives to allocate water to water-efficient crops with low transaction costs. Another option is to base water charges on the authorised water delivered to the farm rather than on the measured crop areas, which could lead to an increase in irrigated areas in saline regions - presumably in kharif as much of the rainfed part of the farm would be converted to partial irrigation and the annual rise in saline water tables might be slowed down.

The best short-term means to conserve water in the Brantas is to enhance allocation of water among irrigation districts, i.e. to increase operational efficiency. Secondly, farmers need to obtain water use rights/permits, if not themselves, then through WUAs, to establish a base for compensation as water is increasingly transferred to urban-industrial users, particularly under drought conditions. Thirdly, farmers need to have more say in cropping strategies and water allocation, and, in that process will likely agree to increase support for O&M of systems. Enhanced canal maintenance will again save water. Finally, in the medium term, enhanced crop cultivation strategies, particularly for rice, and water marketing at the tertiary block level with other sectors, will help save water while not negatively impacting farm incomes. Introducing Systems of Rice Intensification (SRI) seem to increase production while applying less water, but the quantity of water consumed seems to be the same, so that savings are marginal. Besides it seems hard to apply SRI in field-to-field irrigation. Quotas are also hard with field-to-field irrigation; it is impossible to give individual farmers a quota. Farmers will still maximise returns to land and the farmer at the end of the field-chain will not receive any water when such a quota is introduced. To meet the increasing urban demand for water, it is probably necessary to take irrigated land out of production, i.e. retire land to divert water away from agriculture, and investigate new farm management practices.

Tadla in Morocco is the most sophisticated of the surface irrigation systems studied, but still uses rationing to constrain demand. Volumetric water charges are used to achieve cost recovery, which is relatively high. Volumetric charging will continue to play a role in encouraging productive use of water, but volumetric allocations are likely to remain the dominant means of ensuring that demand is constrained to equal supply. It should be noted that to overcome the constraints of inflexibility and the quantity of surface water availably, many farmers have invested in private tubewells, where the unit price of water is more than double that of surface supplied. To control groundwater use, it is recommended to define entitlements for groundwater use. Another solution to declining groundwater levels would be to forbid pumping when groundwater levels fall below a certain threshold level.

Crimea in Ukraine faces quite different problems. Water availability exceeds demand due to the lack of farmer funds for maintenance of irrigation equipment as a result of the instability of agricultural markets and transitional economic and institutional problems. The decline in demand in return requires still higher prices to recover costs from the smaller 'sales' based. The limited demand for water creates a vicious circle of low revenues as demand is low, poor financial viability, inadequate maintenance and consequently deteriorating irrigation equipment. Under these circumstances the potential for an area-based charge should be considered. If all potential irrigators are charged a flat fee to provide basic revenue to the operating agency, plus an additional crop-based fee designed to recover variable costs (energy costs), then the incentive to irrigate is increased (because the marginal cost of irrigating is lowered by the contribution for the area-based charge) and the funding situation of the operating agency is greatly improved. This approach in turn will encourage those with no interest in irrigation to rent their land to those who are. To reverse the process of decreased irrigation, the use of irrigation water could also be stimulated in other ways. Firstly, by making water management more flexible to anticipate to circumstances/wishes by means of making water rights easier to obtain, especially for privatised farmers. Secondly, by reducing uncertainty in agricultural markets.

4.3 Reasons why market-pricing and tradable water rights are not widely applied

In theory market-pricing and tradable water rights can lead to an efficient allocation, but neither instrument has been applied successfully in the case studies due to i) market failure; ii) preferences of society to allocate water according politically defined priorities; iii) practical implementation problems. Experiences from the case studies are reviewed below.

i) Several types of market failure occur in the case study areas:

- The role of free market forces to allocate water among sectors seems limited when there are big differences in the ability to pay -when there is market power- or when it is hard to define values for water, like urban versus environmental usage.
- Irrigation may cause environmental externalities, like waterlogging and exploitation of aquifers beyond its sustainable yield in fresh groundwater areas in Haryana and Tadla, due to the common-pool nature of aquifers. When the market does not take account - internalise - such externalities, it will not allocate resources appropriately.
- Finding the volumetric price at which supply and demand are equal poses a difficult challenge due to uncertainty in the hydrological cycle - within and between seasons - and due to uncertainty in agricultural markets, as in Crimea (due to the transition).

ii) Society may prefer to allocate water in ways that are inconsistent with the likely outcome of a free market. There are often multiple-objectives (an efficient allocation is not always political acceptable). Generally the basic allocation of water among sectors is a political decision, since allocation has so many implications that it can often not be left to the free market. It may for instance trigger socially undesirable changes in income distribution.

- Market clearing prices will not be used to balance supply and demand as it will impose a substantial burden on farm income in Tadla, which is socially not desirable.
- Diverting water away in Egypt from long-developed areas with high productivity to newer less productive areas may reduce overall production. Nevertheless it is a politically priority to expand the irrigated area in backward areas.
- There exist often historical, social, cultural, and religious barriers. Charging agriculture for water and water services is for instance a politically sensitive issue in Egypt. In principle charging for the service of providing water is acceptable, but charging for the water itself is not -making volumetric charging a contentious issue-.

iii) Practical implementation problems

- Important preconditions for the introduction of market-prices and tradable water rights are absent in most study areas (see table 4.1). The design of the irrigation system makes volumetric measurement and disaggregated supply impossible in Haryana and Brantas. The British irrigation system -like in Egypt-, is for instance less well designed for the use of volumetric charges and tradable water rights than the French system -like in Morocco-, as the latter has more accurate distribution and measuring structures. It is determining whether the concept of scarcity was dominant in the original design, like in Morocco. There are currently also no defined rights for groundwater use in Haryana and Tadla. A legal framework to charge for water is not in place yet in Kemry, Haryana and Brantas.

- The transaction costs might block the introduction of market-pricing and tradable water rights since introduction is usually conditional upon the size of additional benefits - efficiency gains - relative to extra costs involved.

Some of these failures may be addressed through the appropriate definition of water rights. Tradable water right are difficult and complex, but are a far more practicable approach than market-pricing. Trading rights will in theory result in an efficient final allocation, the prices prevailing in the market are in practice, however, often inconsistent with objectives sought. Public intervention is needed when it is hard to internalise social preferences or externalities. This list of 'adjustments' to free market outcomes that is required explains why market solutions are rarely found in water management. This study proves that it is hard in practice to solve issues which are essentially political in nature (income distribution, environment, gender) 'by' economics. Such issues can just be better understood 'through' economics.

The essential elements for sound water resources management are listed below. Perry (2003a) sets out a discernable pattern observable in 'successful' scenarios and generally missing in 'unsuccessful' scenarios; he bundled and sliced these elements as follows:

a) Publicly available knowledge of resource availability in time and space (Hydrology);
b) Policies governing resources development and assigning priority usage (Politics);
c) Translation of those policies into allocation rules and procedures such that the water service to each user/sector are clear for any hydrological circumstance (Laws);
d) Defined roles and responsibilities for provision of aspects of service (Institutions);
e) Infrastructure to deliver the specified service to each user (Engineering).

The hierarchy and interdependence among these elements has important implications for the design of interventions to address successful management.

4.4 Conclusions

In the beginning of this chapter the question was raised whether the complexity of market-prices and tradable water rights to address priority problems in the study areas is worthwhile. The experiences from the case studies show that if the objective of managing scarcity is achieved through rationing - which is the most common instrument currently in effect in most study areas - the potential role of market-prices and tradable water rights is rather limited.

Although market-pricing and tradable water rights can lead to an efficient allocation in theory, they are rarely found in practice as outcomes of the market do often not result in a water allocation that meets the legitimate concerns about environmental, social and other factors. In part this is because of market failure. Besides outcomes of the market do often not result in an allocation that meets preferences of society since water is a basic human need that is largely unsuited to free market allocation. Furthermore, there are various practical implementation problems. This explains the observed absence of market solutions and potentially limited role of market-pricing and tradable water rights in water management.

The experiences from the case studies show that volumetric water charges will raise funds. Whether water charges will reduce demand depends on a number of preconditions that have to be met. There are legal and regulatory requirements (specification of price-related water rights), operational requirements (vary supply to individual user and adequate accounting procedures) and economic requirements (price of water must be significant in the economics of the farm). As the prerequisites for using water charges as a demand management tool are numerous and are clearly well beyond present capability of several of the case studies (due to the existing design of the irrigation system, institutional arrangements that are not in place yet and substantial impact that charges will have on farm income - if used to balance supply and demand -), it becomes that there is no clear role for water charges other than cost recovery. Simple crop- or area-based charging systems with low administrative costs and a high degree of transparency seem, however, to be more suitable to achieve cost-recovery objectives.

As some of the preconditions, such as the design of the irrigation system and cultural and religious barriers, can not be easily changed in the short run, they can be considered as given. The recommended instruments depend consequently on the time horizon. In the long run actions can be taken to remove blocking factors and put the required preconditions in place.

As explained above volumetric water charges will only have a significant impact on demand for water where (a) the user has the option to take more or less water and (b) the price of water is substantial in relation to the costs of managing with less. Both conditions are rarely met as in large-scale irrigation schemes disaggregate services at the farm level can not be provided and the price of water is generally so low as to be insignificant in a farmers management decision, whereas raising the price is politically sensitive. The role of market-pricing and tradable water rights seems therefore limited for large-scale irrigation systems. It may, however, be more suitable for small-scale privatised systems.

It is recommended to study practical means of defining and enforcing sustainable groundwater rights in order to ration groundwater use. Institutional reform, in terms of enforcing rights and providing mechanisms to protect third-parties, will require huge effort.

Finally, we can conclude that economics helps us identify issues which are essentially political in nature, but does not prescribe solutions - rather giving guidance as to where solutions may lie, and the extent to which recommended economic tools can support solutions. General guidelines for the use of instruments are difficult to establish, since the suitability of instruments depends on the characteristics of the situation (local circumstances).

5. Conclusions

5.1 General conclusions

Looking at five case studies shows that there is a wide range of problems/objectives and currently applied solutions. Not all economic instruments are applicable to all objectives, often more instruments are needed simultaneously. A mixture of instruments - most commonly, rationing to achieve resource sustainability and fairly simple charging mechanisms to achieve financial sustainability - is needed to achieve multiple-objective. Sophisticated instruments such as market-pricing and tradable water rights have limited applicability and a low priority in the case-study areas, which are probably typical of many developing country situations. This approach can be applied to other case study areas as well

It can be concluded that effective resource management is most readily achieved through quotas/water rights, which also encourage farmers to seek the most productive use of water. However, in some cases implementation of quotas at the farm level is impossible with the available infrastructure - a point that applies to all rice systems. Quotas provide the basis for tradable water rights, which will allow economic forces to work. Tradable water rights offer additional gains through the potential for reallocation of water between users. Institutional reform, in terms of defining and enforcing water rights and providing mechanisms to protect third parties requires huge effort, but is easier than market-pricing.

The observations from the case studies confirm the conclusions presented in the earlier literature review: charges that cover O&M are generally affordable, but are unlikely to bring demand and supply into balance, whereas market clearing prices will impose a substantial burden on farm economic welfare and are therefore not desirable. Volumetric water charges are unlikely to be relevant to demand management - even though some study areas have volumetric measurement, control and monitoring systems - because the water charge at which demand and supply would be balanced is so high as to substantially reduce farm incomes. This socio-political problem, plus the technical and administrative complexity of measuring and accounting for water, and the crucial distinction between water applied to the field and water consumed by the crop make water charges an unsuitable approach to balancing supply and demand. Water charges seem to mainly reduce irrigation water applied instead of water consumed. Higher volumetric water charges will encourage more productive use. The issue is whether implementation costs exceed productivity gains.

Sustainable financial management can best be achieved through fairly simple crop- or area-based charging mechanisms with low administrative costs and a high degree of transparency. Volumetric water charges are too expensive in this respect.

In this study it became clear that it is not likely that farm management practices that increase the productivity of water, will reduce water consumed as demand for inputs will tend to increase as productivity increases (assuming it is possible to expand the irrigated area). This is an extension of existing work in this field.

It is interesting how frequently the reality or possibility of groundwater depletion comes up. Policies for sustainable groundwater management are, however, often missing. Although it is recognised that control of imbalances is a matter of concern for the long-term viability of irrigated agriculture, it is difficult to address in practice.

This study proves that it is hard in practice to solve issues which are essentially political in nature (income distribution, environment) 'by' economics. Such issues can just be better understood 'through' economics. It provides the means of analysing implications of various ways of allocating water and to design suitable measures to improve management.

5.2 Research recommendations

It is recommended to study the relationship between reliability and productivity of water, as it has implications for the productivity of water in agriculture and hence the water required to meet specific levels of production and the design and management of the irrigation system. Water availability can be unreliable in terms of three parameters: rate of supply, duration of supply and periodicity between successive deliveries. While there has been extensive research in the impact on actual yield of variations in water availability, little is known about the impact on farmer behaviour of his ex ante expectations of variation in water availability. It is likely that the farmer will be ready to invest more in a chosen crop if the availability of water is more secure: he will be ready to select high yielding but water sensitive varies, prepare the land carefully, plant intensively, and invest in high quality seeds, fertilisers and pesticides. It is therefore recommended to derive the value of reliability of water delivery. It is likely that returns to groundwater - with a rather reliable supply - are higher than returns to canal water with a rather unreliable supply.

In order to allocate the right share of irrigation costs to the various beneficiaries it is recommended to develop methodologies to quantify the social benefits and social costs of irrigation. Usually only the private benefits (in terms of direct productive impact) are quantified and not the social benefits of irrigation, whereas the government may attach values to other objectives such as water allocations that contribute to more equitable income distribution and poverty alleviation or that encourage rural development, or reduce food costs for consumers or contribute to food security. It is, however, hard to value such non-marketable goods in monetary terms. There is a clear need to develop methodologies for quantifying i) the value of irrigation water for indirect beneficiaries and ii) costs to third-parties. It seems interesting in this respect to study what information about the value of water can be derived from analysis of prices prevailing in tradable water rights systems.

It is also recommended to study to what extent demand for water will increase when the irrigation efficiency increases due to technology adoption, as the consumed part of water diverted increases (which makes water cheaper). Improved irrigation technologies increase the productivity of water and consequently the profitability of water use, which may induce an increase in water consumed when it is possible to expand the irrigated area.

Finally, it is recommended to improve ways to monitor the impact of economic instruments on water consumed instead of on water applied. It is complex to measure changes in actual consumption, since where excess water applied is recaptured through groundwater recharge or re-use of drainage water the concept of 'losses' is misleading.

References

Bhatia, R., *Cost Price and Value of Water in Alternative uses: A Case Study of Subana Rekha River Basin*. Paper presented at the international Conference On Sustainable Development Of Water Resources, New Delhi, 2000.

Briscoe, J., *Water as an economic good: the idea and what it means in practice.* Paper presented at the World Congress of the International Commission on Irrigation and Drainage, Cairo, 1996.

Coase, R., 'The problem of social cost'. In: *Journal of Law and Economics* 3 (1960), pp. 1-44.

De Fraiture, D. and C. Perry, *Why is irrigation water demand inelastic at low price ranges*. Paper presented at the conference on Irrigation Water Policies: Micro and Macro Considerations in Agadir, Morocco June 15-17, 2002.

FAO, *Reforming water resources policy: a guide to methods, processes and practices.* Irrigation and Drainage Paper No.52. Food and Agriculture Organisation, Rome, 1994.

Garrido, A., 'Pricing for water use in the agricultural sector'. In: *Pricing water, economics, environment and society*. Conference Proceedings of DG Environment of the European Commission. Sintra, 6-7 September 1999.

Gibbons, D.C., *The economic value of water: resources for the future*. Washington, 1986.

Gollehon, *Rural Development Perspectives*. No. 14-2. August 1999

Hartwick, J.M. and N.D. Olewiler, *The economics of natural resource use.* Addison-Wesley, Reading, 1998.

Hellegers, P.J.G.J. and Van Ierland, E.C., 'Policy instruments for groundwater management for agriculture and nature in the Netherlands'. In: *Environmental and Resource Economics* 26 (2003), pp. 163-172.

ICWE, *The Dublin statement and report of the International Conference on Water and the Environment.* Development issues for the 21st century. Dublin. 26-31 January, 1992.

OECD, *Transition to full-cost pricing of irrigation water for agriculture in OECD countries*. OECD, Paris, 2002.

Perry, C.J., 'Determinants of Function and Dysfunction in Irrigation Projects, and Implications for Performance Improvement'. In: *Water Resources Development* 11 (1995) 1.

Perry, C.J., D. Seckler and M. Rock, 'Water as an Economic Good: A solution or a problem'. In: M. Kay, T. Franks and L. Smith (eds.) *Water: Economics, Management and Demand*. E & F Spon, 1997.

Perry, C.J., *Control of Groundwater Use: The Limitations of Pricing, and a Practical Alternative (with Mehmood al Hassan).* Regional Groundwater Management Seminar, Islamabad Pakistan, October 2000.

Perry, C.J., *Non-State Actors and Water Resources Development; An Economic Perspective.* Non-State Actors and International Law, Issue 1, Vol 3, 2003a.

Perry, C.J., *Water pricing: some important definitions and assumptions*. Occasional Paper No 59. SOAS, Water Issues Study Group. 2003b.

Robbins, L., *The theory of economic policy in English classical political economy.* London, MacMillan., 1952.

Rogers, P., R. Bhatia and A. Huber, *Water as a social and economic good: How to put the principle into practice.* Global Water Partnership / Swedish International Development Cooperation Agency, Stockholm, Sweden. 1998.

Rogers, P., R. de Silva and R. Bhatia, 'Water is an economic good: how to use prices to promote equity, efficiency and sustainability'. In: *Water Policy* 4 (2002), pp. 1-17.

Savenije, H., *The socio-economic value of water: knowledge gaps and research questions in integrated water resources management.* Paper presented at the UNESCO-WOTRO Conference on Water for Society, Delft, 8-10 November 2000.

SWWF, *Forum report on water and economics of the Second World Water Forum*. The Hague, 2000.

Tregarthen, T.D., 'Water in Colorado, Fear and Loathing in the Marketplace'. In: T. Anderson (ed.), *Water Rights* (119). 1983.

List of definitions and terms

The nature and role of economic instruments is complex. Discussion and debate can only be based on clear and mutually understood terminology, and we therefore summarise below the terms used in this report:

Rationing is allocation of water to specific uses or users on a quantitative basis. The quantity may be specified in volume terms or as a fraction of the available supply. The amount of water supplied to the user is his ration or quota.

Charge for irrigation: includes all fees payable by the irrigator, which may be based on crops irrigated and/or volume of water received and/or fixed charges.

Cost of irrigation includes operation, maintenance and replacement of facilities, capital costs in the form of amortisation charges and the cost of collection.

Price is the volumetric price of water - how much extra the irrigator pays per unit of water received. Often, with crop-based or quota systems, the marginal price is zero (even though the charge may be high) and once the farmer has decided to irrigate there will be no marginal incentive to save water.

Value of irrigation water is the net income received by the farmer per unit of water consumed. It is calculated as the net value of crop produced divided by the irrigation water consumed by the crops. In this study we do not attempt to derive marginal returns to water (the extra income that a farmer would derive from an additional cubic meter of water). In general, under conditions of water scarcity, average value is a reasonable proxy for marginal value because farmers are trying to maximise the return to the scarce resource.

Volumetric charging and market-pricing are closely related concepts. Volumetric charging occurs when the quantity of water provided is determined by an allocation procedure such as a quota, or water for an agreed cropping pattern, and the charge is based on the actual quantity of water delivered - but the farmer cannot simply demand as much water as he might wish to apply at the agreed price. Market-pricing implies that water is available at a set price, and the farmer decides how much water to take at that price.

Tradable Water Rights allow users with an assigned water quota to sell the quota to another user (or buy additional quotas from others).

List of abbreviations

AER	Aerobic Rice
ASNS	Alternate Submerged - Non Submerged
AWD	Alternate Wet-Dry
BBMD	Bhakra-Beas Management Board
BDWM	Basin Departments of Water Management
CMD	Canal Management Department
GCRPS	Ground Cover Rice Production System
GDP	Gross Domestic Product
GNI	Gross Net Income
GOH	Government of Haryana
IAS	Irrigation Advisory Service
ICM	Integrated Crop and Resource management
ID	Irrigation Department
IFPRI	International Food Policy Research Institute
INT	Intermittent Irrigation
IIP	Irrigation Improvement Project
ISF	Irrigation Service Fee
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
LEI	Agricultural Economics Research Institute
MoA	Ministry of Agriculture
MWRI	Ministry of Water Resources and Irrigation
NCC	Northern Crimean Canal
NWRP	National Water Resources Plan
O&M	Operation and Maintenance
ORMVA	Office Regional de Mise en Valeur Agricole
RDWM	Regional Departments of Water Management
SCWM	State Committee of Water Management
SRI	Systems of Rice Intensification
SYL	Sutlej Yamuna Link
WRBRK	Water Right with Brokerage
WUA	Water User Association
WUAF	Water User Association Federation
WVP	Water Valuation Pricing

About the authors

Prof. Dr Chris J. Perry - visiting professor at Cranfield University in the UK - has twenty years' experience in irrigation and water resources project design and implementation with the World Bank followed by five years' experience at the International Water Management Institute (IWMI) in Colombo, Sri Lanka. He has particular interests in the overall framework within which successful water management is practised; the economics of water and water management; performance assessment; and the potential of remote sensing to contribute to improved understanding or water systems.

Dr Petra J.G.J. Hellegers has ten years' experience in the economics of water at the Agricultural Economics Research Institute (LEI) in The Netherlands. Her Ph.D. thesis was about the conflicting interests between agriculture and nature with respect to water management from an economic point of view. She has particular interests in the role of economic instruments in analysing the implications of allocation of scarce water resources among users on the basis of trade-offs analysis that have financial, economic, and/or environmental implications for those directly concerned, as well as society more generally.

Appendix A Location and data of study areas

The locations of the study areas are shown in Figure A.1 and some data in Table A.1.

Figure A.1 Geographical representation of the study areas

Table A.1 Socio-economic, irrigation and climate data

Study area	Egypt	India	Indonesia	Morocco	Ukraine
Population (millions)	66.4	1,033.4	211.7	29.6	48.7
Average annual growth 1996-2002 (%)	1.9	1.7	1.3	1.6	-0.8
In rural areas (% of total population)	57	72	57	43	32
Gross Net Income per capita ($)	1,470	470	710	1,190	770
Percentage of agriculture in GDP (%)	16.8	25.0	17.5	16.1	16.9
Percentage of industry in GDP (%)	33.0	25.9	44.5	31.1	39.3
Percentage of services in GDP (%)	50.2	49.2	38.1	52.8	43.8
Land area (million ha)	99.5	4.4a)	190	71	2.6c)
Irrigated area (million ha)	3	2.9a)	3.3b)	1.6	0.4c)
Percentage of agriculture in withdrawal (%)	83	92	93	88	88c)
Rainfall (mm/yr)	0	545a)	2,500	300	400c)
Evapotranspiration (mm/yr)	1800	1,550a)	1,400	1,200	1,000c)

a) Haryana; b) Java; c) Crimea.
Source of the upper part of the table: World Bank, 2003.

Appendix B Framework used to derive returns to water

It is proposed to use an existing Excel-based spreadsheet model. AGWAT(F) is an Excel Spreadsheet with six 'worksheets', developed by Perry. Three of these worksheets contain only data which the user is required to insert. The remaining three worksheets contain only computed results. Locations where data may be entered are Grey cells in this Appendix. The three input data sheets are Prices Data, Farm Data, and Labor and Irrigation, which contain sample data. The data are invented as a basis for explaining the analysis.

Data Entry

The *Prices Data* Worksheet contains the name of the currency (Rs), names of the of the crops (Rice, Maize, Cotton, Wheat), prices for each crop, any byproduct, and seed (Rs3000/ton, Rs100/ton and Rs40/kg in the case of Rice) and the cost of canal irrigation services which may be either per hectare (Rs600 for rice) or per cubic meter. Fertiliser prices are also listed (Rs4000/T for N). The observed minimum and maximum daily rates for hired labour (Rs15 and Rs50) are specified, as are the minimum and maximum charges for well water (Rs50 and Rs100) per thousand cubic meters.

PRICES

CURRENCY: Rs

	Crops Rs/Ton	Byprod Rs/Ton	Seeds Rs/kg	Water /ha	Water /000m3
Rice	3,000	100	40	600	
Maize	2,000	200	20	200	
Cotton	7,500	150	150	300	
Wheat	4,000	500	70	400	

Fertilisers-Rs/T

N	4,000
P	2,500
K	3,000

Hired Labor-Rs/day

min	15
max	50

Groundwater-Rs/000m3

min	50
max	100

The *Farm Data* Worksheet includes the farm size, the monthly availability of family labour, and the on-farm irrigation efficiency (2ha and 25 days/month, and 80% respectively). The basic input-output data for the farm are included in a table - the cropping pattern for each of the crops specified in the *Prices Data* table (in terms of percentage of the farm area - this in the example, with 40% of the farm area under Rice, the physical area under Rice would be 2ha x 40%, or 0.8ha). Yields of the crop and any by-product are specified, together with input usage rates for fertilisers and any chemical or other 'per hectare' inputs. The available family labour is also specified (25 days per month in the example). Note that the total percentage area cropped (155%) is in excess of 100%; the first three crops are grown in one season, while the wheat is grown in another season.

Farm Size	2.0	Ha
Family Labor Available-day/month	25	
Farm Irrigation Efficiency (%)	80	

	AREA	Output (T/ha)		- -- - - - Inputs (kg/ha) - - - - - -				- - Rs/ha - -	
	%	crop	byprod	N	P	K	Seed	Chem	Other
Rice	40	3.5	0.8	70	20	60	50	500	
Maize	20	2.5	0.5	20		10	30		
Cotton	20	2	0.2	120	90	40	40	1000	
Wheat	75	2.5	0.5	80	80		40	200	

The *Labour and Irrigation Data* Worksheet includes the monthly inputs required per hectare of crop. Crop irrigation requirements are specified in terms of millimeters per month, and should be specified by the user to include effective rainfall. Labour requirements are specified in the same format. In the example, Rice requires 50 days labour in June per hectare of crop, and the farm level requirement will be computed based on the farm area under Rice. AGWAT does not compete with programs such as CROPWAT, which should be used for more detailed analysis of crop water balances. Finally, the monthly availability of canal irrigation water to the farm is specified in thousands of cubic meters - here assumed to be constant at 3,000 m^3/month from June to October.

LABOR REQUIREMENTS
(Days per ha of Crop)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rice						50	30	10	10	10	60		170
Maize							20	20	20	10	30		100
Cotton					20	20	20	20	15	20	20	60	195
Wheat	10	10	5	20									45

IRRIGATION REQUIREMENTS AND AVAILABILITY
mm/month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total ('000 m3)
Rice						500	300	300	300	600			20
Maize							150		150	150			5
Cotton					250	200	150		150	150	100		10
Wheat	250	150	150	250									8
Canal Supply (m3)						3,000	3,000	3,000	3,000	3,000			**15,000**

Results

In the *Labour and Irrigation Demand* Worksheet, the upper table shows the results of multiplying the Farm Size by the percentage area under each crop by the monthly labour demand per hectare. For Cotton in May the relevant figures are 2ha x 20% x 20 days/ha/month, or 8 days. The total demand is calculated as the sum for each month of the demand from each crop. In May, with Cotton the only crop using labour, the total is 8. Since this is less than the available family labour (25, from *Farm Data* worksheet), there is no need to hire labour. In June, however, the total demand is 40 days, so 15 days are hired.

FARM IRRIGATION DEMAND, SOURCES OF SUPPLY AND COSTS
(m3 / month)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rice						5,000	3,000	3,000	3,000	6,000			**20,000**
Maize							750		750	750			**2,250**
Cotton					1,250	1,000	750		750	750	500		**5,000**
Wheat	4,688	2,813	2,813	4,688									**15,000**
Demand	**4,688**	**2,813**	**2,813**	**4,688**	**1,250**	**6,000**	**4,500**	**3,000**	**4,500**	**7,500**	**500**		**42,250**
Canal Supply						**3,000**	**3,000**	**3,000**	**3,000**	**3,000**			
Vol Charge (Rs)													
Pumped (m3)	4,688	2,813	2,813	4,688	1,250	3,000	1,500		1,500	4,500	500		**27,250**
Rate (/'000 m3)	100	78	78	100	59	80	62		62	98	50		**765.7**
Pump Charge (Rs)	468.7	218.3	218.3	468.7	73.7	239.6	92.9		92.9	439.9	25.0		**2338.1**

Note that in the price data we specified the maximum and minimum hired wage rates (50 and 15, respectively). AGWAT computes the total demand for hired labour in each month, then assigns the maximum price to the month of maximum demand (November, where 43 days of hired labour are required) and the minimum to the month with minimum hiring (April, 5 days), and scales between these two extremes depending on demand. In June, with an overall demand of 23 days hired labour, the daily rate is computed at Rs32/day so that the cost of hiring is 21 days at Rs32/day, or Rs726. The associated table - Farm Irrigation Requirements - computes the monthly and total demands by crop in a similar fashion.

FARM LABOR DEMAND
(Days)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rice						40	24	8	8	8	48		**136**
Maize							8	8	8	4	12		**40**
Cotton					8	8	8	8	6	8	8	24	**78**
Wheat	15	15	8	30									**68**
Demand	**15**	**15**	**8**	**30**	**8**	**48**	**40**	**24**	**22**	**20**	**68**	**24**	**322**
Family Labour	**15**	**15**	**8**	**25**	**8**	**25**	**25**	**24**	**22**	**20**	**25**	**24**	**236**
Hired Labour				**5**		**23**	**15**				**43**		**86**
Wage Rate (Rs/day)				15		32	24				50		
Wage Payments (Rs)				75		726	363				2,150		**3,314**

The water requirements are totaled by month, and where canal supplies are inadequate to meet demand (for example, June where demand is 6,000 m^3 and canal supplies are 3,000 m^3) water is assumed to be pumped to meet the deficit. The cost of pumping is scaled between maximum and minimum demands (Rs100/m^3 in January and Rs 50/m^3 in November) as in the case of labour, to allow variation of supply with demand. Note that if maximum and minimum prices are set equal, then the cost of water will not vary with demand. Also, if canal supplies are set to zero, then all water will be pumped. If the required supply of pumped water is greater than known availability, it is up to the analyst to either (a) reduce the cropped area, or (b) reduce crop yields to reflect water shortage.

The *Crop Budgets* table computes returns by crop on a per hectare basis. Value of production is simply yield multiplied by price (3.5 t/ha x 3,000Rs/t = Rs10,500/ha for Rice, plus 0.8t/ha x 100Rs/t = Rs80/ha for the by-product). The costs of NPK and other per hectare inputs are similarly calculated. The cost of hired labour is more complex, because the costs of hiring must be allocated on a crop-by-crop basis. This is done by computing the proportion of total demand that each crop accounts for in each month, and distributing the total cost of hired labour for the month on this basis.

CROP BUDGETS PER ha

Crops	VALUE OF PRODUCTION Crop	by-product	GROSS RETURN	COST of INPUTS and WATER NPK	Other	Labor	/ha	/'000m3	Pumped	TOTAL COSTS	NET RETURNS Average	Marginal
	Rs/ha											
Rice	10,500	80	10,580	510	2,500	2,926	600		844	7,380	3,200	(32)
Maize	5,000	100	5,100	110	600	1,130	200		187	2,228	2,872	1,790
Cotton	15,000	30	15,030	825	7,000	1,117	300		534	9,776	5,254	3,927
Wheat	10,000	250	10,250	520	3,000	50	400		916	4,886	5,364	5,114

The cost of Pumped Water is similarly distributed among crops on the basis of the cost of pumped water in any month and the proportion of irrigation demand for each crop. With Gross Returns and Total Costs computed on a per hectare basis, the Average Return to each crop is calculated as the Gross Return less all costs.

The Marginal Return is an additional indicator of the attractiveness and returns to each crop. Here the costs are based on the situation if an additional hectare of the crop is grown. Where labour is already hired in a particular month (or where water is purchased from a well) then all additional labour (or water) is purchased at the full cost - hence leading to higher costs than in the 'average' case where costs are a mixture of 'free' family and hired labour, and 'cheap' canal water plus pumped water.

Farmers will generally be interested to increase production of the crops where the marginal return is highest - and it is interesting to observe that in the example, the marginal return Rice is sharply lower than the Average Return - because of the high incidence of hired labour in the cost structure, while Maize remains relatively attractive. Based on Average returns, we would expect farmers to be more interested in increasing rice than wheat.

The Farm Budget provides a picture of the overall farm business, based on the actual area under each crop (note that the Crop Budgets are per hectare of crop, the farm budget is for the whole farm). As well as showing the gross and Net Returns - which are indicators of the returns to land, the table also indicates the return to family Labour and to Water.

FARM BUDGET

Crop	Income per ha Rs	Area (ha)	Farm Income Rs	COSTS Inputs	Labour	Water	**Net Income Rs**	Family Labor Use (days)	Return Rs/day	Water Use 000 m3	Return Rs/m3 Gross	Net
				Rs								
Rice	10,580	0.80	8,464	2,408	2,341	1,155	**2,560**	77	33	20.0	0.4	0.1
Maize	5,100	0.40	2,040	284	452	155	**1,149**	29	39	2.3	0.9	0.5
Cotton	15,030	0.40	6,012	3,130	447	334	**2,102**	66	32	5.0	1.2	0.4
Wheat	10,250	1.50	15,375	5,280	75	1,974	**8,046**	62	129	15.0	1.0	0.5
Total/Ave	10,287	3.1	31,891	11,102	3,314	3,618	**13,856**	235	59	42.3		

Cropping Intensity = 155%
Utilization of Available Family Labor = 78%
Proportion of Family Labor in Total Used = 73%

Interpreting the results

The first point to consider in interpreting the results is whether they survive a 'sanity check' - Do specific crops show huge positive or negative returns? Is the demand for water much higher or lower than observed availability? Is the calculated need for hired labour consistent with observed scarcity or excess of available labour? This review will often point to flaws in the data, and errors in data entry, and is always a useful and rewarding exercise.

From the farmer's viewpoint, his primary goal is to maximise Net Farm Income. Are there obvious opportunities to do this? The *Crop Budgets* show that Cotton has a considerably higher Average Return (Rs5,254/ha) than Maize (Rs2,872/ha). We can quickly test the impact on farm income of switching 1% of the area from Maize to Cotton, so that the Cropping Pattern in the Farm Data table now reads Rice 40%; Maize 19%; Cotton 21%; Wheat 75%. The resulting Farm Budget is shown below. Comparing this with the base scenario, we see that income has fallen by shifting to the apparently more profitable crop.

Why? In the base case, Maize income at the farm level was Rs1,149, Cotton income was Rs2,102 (total Rs3,251). Corresponding data for the new scenario, above are Rs1,084 and Rs 2,183 (total Rs3,267 - a gain of Rs16). But the higher labour demand of Cotton, competing with Rice in high-demand months induced a fall in Rice income from Rs2, 560 to Rs2, 480 five times the gain from the increase in Cotton!

FARM BUDGET

Crop	Income per ha Rs	Area (ha)	Farm Income Rs	COSTS Inputs	Labour	Water	**Net Income Rs**	Family Labor Use (days)	Return Rs/day	Water Use 000 m3	Return Rs/m3 Gross	Net
				-------- Rs ---------								
Rice	10,580	0.80	8,464	2,408	2,418	1,158	**2,480**	77	32	20.0	0.4	0.1
Maize	5,100	0.38	1,938	270	437	147	**1,084**	28	39	2.1	0.9	0.5
Cotton	15,030	0.42	6,313	3,287	492	351	**2,183**	69	32	5.3	1.2	0.4
Wheat	10,250	1.50	15,375	5,280	95	1,973	**8,027**	62	128	15.0	1.0	0.5
Total/Ave	10,351	3.1	32,090	11,244	3,442	3,630	**13,774**	237	58	42.4		

Cropping Intensity = 155%
Utilization of Available Family Labor = 79%
Proportion of Family Labor in Total Used = 73%

Appendix C Egypt - Kemry

Abstract
The challenge that faces managers of Egypt's irrigation system is how to deal with scarcity. Increasing demand from other sectors, more intensive irrigation in the 'old lands', and expansion of the irrigated area in 'new lands' has effectively 'created' scarcity. Presently volumetric allocation systems are not feasible to balance supply and demand- as maintenance of credible records of deliveries at the field level is hard. Any attempt to introduce water measurement has enormous implications on how the system is operated, the infrastructure needed and the formalisation of rights. The system in Egypt is designed to deliver full crop requirements. To allocate the available supply equitably among all users, in a transparent and systematic fashion three options are proposed: 1) controls can be placed and enforced on crops such as sugar cane; 2) seasonal canal closures can be implemented to prevent irrigation in the hotter months; 3) areas can be rotationally closed on a seasonal or annual basis. An increase in field irrigation efficiency will not save water at the basin level. The limited degree of cost recovery is also a problem.

1. Introduction

In 2002 Egypt had a population of 66.4 million -growing at 1.9 % per year- of which 57% lives in rural areas. GNI is $ 1470. Agriculture accounts 16.8% of GDP, industry accounts for 33% of GDP; services (a.o. tourism) account for the remaining 50.2% of GDP (World Bank, 2003). About 32% of the population is employed in agriculture. The total size of Egypt is 99.5 million ha, 97% of which is desert. Irrigated agriculture accounts for 83% of total water diversions.

The Egyptian climate is arid - except for small areas near the coast, the country has no reliable rainfall - and agriculture is only possible when supported by irrigation from the river Nile. The present system of irrigation has evolved in three stages: first, for millennia, Egyptian farmers have utilised the high flows of the Nile in August and September for local irrigation near the river. This system was substantially expanded by the construction of the Nile Barrages in the 1860s, allowing larger quantities of water to be diverted to extended irrigated areas. With the construction of the High Aswan Dam in the 1960s, Egypt moved from an era of seasonal flood irrigation to an era of perennial, controlled irrigation.

Under an agreement with Sudan, the available water to both countries (the vast majority of which is runoff from countries upstream in the basin) is shared so that in an average year, Egypt is entitled to 55.5 billion m^3, Sudan receives 18 billion m^3, and 10 billion m^3 is estimated to evaporate from Lake Nasser. Storage in Lake Nasser is in excess of 100 billion m^3 - providing the capacity for substantial inter-annual regulation. In the early 1980s, a series of drought years led to severe depletion of the reservoir; more recently rainfall has exceeded average levels, and Aswan actually spilled water for the first time a few years ago.

In high or low-flow years, allocations under the agreement are pro-rata, but in fact Sudan has yet to exploit its full allocation so that Egypt has generally had access to more water than strictly provided under the agreement - especially during the recent period of high rainfall, when as much as 65 billion m^3 per year has been available.

Egypt's irrigated area is about 3 million hectare: some 2.16 million hectare are the 'old lands', located in the Nile basin and Delta; 0.76 million hectare are 'new lands' much of which is located outside the Nile's drainage basin, so that any excess irrigation supplies to these areas are lost to the system. A small additional area (0.08 million hectare) is irrigated from oases. Cropping intensity is about 200% and average farm size is about 1 ha.

Increasing agricultural production through higher yields on existing areas and expanding the irrigated area has always been an objective of the Egyptian Government. This was the objective of construction of the diversion barrages in the nineteenth century, and of the High Aswan dam in the twentieth century. The Land Master Plan (LMP) of 1986 estimated Egypt's additional reclaimable lands at 1.43 million ha. The Ministry of Agriculture and Land Reclamation (MALR) and the water policy of 1990/91 set by the Ministry of Public Works and Water Resources (MPWWR) projected reclamation of 0.88 million ha by the year 2000, equivalent to 63,000 ha/year from 1986 to 2000. This target proved to be over-optimistic, and would in any case have required almost a 20% increase in irrigation water supply (Mohamed, 2001).

Water availability to the existing irrigated areas in Egypt will become an increasing constraint to agricultural production, given the plans of the government to expand the irrigated area by constructing additional centre-pivot schemes in the 'new lands', and an expansion of irrigation into the Sinai desert. Besides there is a rapid increase in population and water demanding developments in industry. The pressure on the available water resources is severe: the present per capita availability of water is about 1,000 m^3/year, which will continue to fall in the future.

Although Nile water has low salinity (0.3 dS/m), it brings salts into the soils at a rate of 8.0 tons/ha/yr. To date, Egypt has been successful in controlling this salinity - in the earlier periods, the annual flushing of the flood irrigation maintained the balance; more recently a succession of drainage projects has allowed removal of salts, but there are signs - particularly in the Northern Delta - that salinity (associated with high water tables) will require careful management. More than 2 million hectare are provided with sub-surface drainage systems.

Observations at field level suggest that on-farm irrigation efficiency is low, but in fact 'losses' are captured by drains and returned to the system. Reuse of drainage water has contributed to an overall water use efficiency that is one of the highest in the world (Davis and Hirji, 2003). Although Egypt's field irrigation efficiency is thought to be inefficient - only 40% of applied water is actually used by the crop - an increase in the local efficiency is of little benefit, as losses in one location are recovered elsewhere (through drainage water returning to the main Nile system, through local pumping from drains, or indirectly through capillary rise from the relatively high water tables). Besides some outflow to the Mediterranean is necessary to meet flushing requirements of the system. In an average year, less than 10 billion m^3 of water flows to the Mediterranean, which is probably close to the minimum necessary for flushing the system, so the scope for 'saving' water through improved irrigation technology is minimal. Hence improvements in local 'efficiency' within the traditional irrigated areas will not save water at the basin level. Due to extensive reuse agriculture has a higher water use efficiency than domestic and industrial use - as a result of lacking incentives for optimal consumption -. Water may consequently return to agriculture (kind of superficial gain). However, high local 'efficiency' in the 'new lands' is important as excess deliveries in the 'new lands' will not return to the system.

2. Water problems, policies, infrastructure and institutions

2.1 Water problems and policy objectives

The stated policy of the Government of Egypt for agriculture is to expand production, through increasing the cropping intensity in 'old lands' and expanding the irrigated area through construction of 'new lands'. Egypt already has exceptionally high yields, but there is scope for switching to higher value crops - especially moving away from sugar cane, which is low value and water intensive, towards sugar beet, and also reducing the area under rice (though this is more technically challenging as rice is often grown where water tables are high, or to maintain a fresh water layer over saline aquifers). Early-maturing varieties of rice with a shorter growth period may also reduce water demand, mainly as a result of less evaporation from paddy land.

With only 3% of its land area under cultivation, Egypt has no shortage of land: in the absence of rainfall, irrigation water is the dominant constraint to agricultural production in Egypt. There has been controversy for more than a decade about the scope for increasing the use of water for irrigation: the construction of the Aswan dam increased the volume of controlled water and its reliability enormously - and it was anticipated at that time that vast expansion of the irrigated area would be possible. What was not anticipated was the rapid response of existing irrigators to increase their cropping intensity - so that much of the incremental water from Aswan was consumed in the 'old lands'. Nevertheless the political commitment to expanding into 'new lands' remained a central theme of government policy.

Egypt's water balance is in fact already precarious: outflow to the Mediterranean is in the order of 10 billion m^3/yr and water quality near the coast is such that it is difficult to argue that a much lower quantity will be sufficient to maintain the required salt and pollutant balance. It is widely believed that industrial and sewage pollution could be better controlled, so that the necessary outflows are reduced. This in turn will release a fraction of current outflows for consumptive re-use. However, according to the latest World Bank project proposal (World Bank website) predicted demand for water in Egypt by 2017 is 88.7 billion m^3/yr - and significant contributions to this total are expected to come from water saving in irrigation and optimal groundwater use. Such targets are difficult to understand: Egypt's water right from the Nile is 55.5 billion m^3/yr. With the exception of limited and erratic rainfall near the coast, this is the only water available to Egypt on a renewable (sustainable) basis. Flows to the sea might be reduced - but overall consumption cannot exceed annual water availability without genuinely 'new' sources (such as desalinisation) or deliberate depletion of aquifers.

The limited degree of cost recovery is also a problem. Greater emphasis is now put on cost recovery mechanisms so that resources for O&M must come from the direct beneficiaries (Barakat, 2002). Charging agriculture for water and water services remains, however, a politically sensitive issue, as it has historical, social, cultural, and religious dimensions. Often it is argued that investments have been made in the national interest - to ensure food security, develop 'new lands', or diversify the economy - implying broader goals than the direct productive impact on those receiving the service. Certainly until the mid-1980s agricultural prices were controlled at low levels by the government and indirect taxes on the sector were very high. More recently, these controls have mostly been removed: farm incomes have risen by about 25% in real terms, and government revenues have fallen.

2.2 Existing policy instruments

Agricultural water use is not directly charged for: only a fixed area-based tariff (independent of crop type or volume used) is included in the land tax paid by farmers, but this is far below the O&M costs (Mohamed, 2001). Besides, there is only a limited degree of cost recovery for infra-structural improvements. For example, the costs of investment in the installation of drainage and improvement of mesqas is recovered, but over a long period of time and with subsidised interest rates and no allowance for inflation. In consequence, although nominal recovery is high, the actual recovery in real terms is a small fraction of the costs (only 35% according to Perry, 1996).

Crop-specific land taxes are proposed, but remain politically controversial. The Ministry of Agriculture (MoA) is bigger and more influential than the Ministry of Water Resources and Irrigation (MWRI), and they have sometimes conflicting interests in pricing and charging policies. For example, cultivation of rice is supposed to be restricted in the south in order to conserve water (which is of concern to the MWRI), but fines are rarely enforced because this would discourage production (which is of concern to the MoA).

For groundwater extraction a license is needed. About 5% of total water use consists of groundwater. The renewable groundwater resource is based entirely on seepage from channels and fields. Fossil groundwater is also used in some oasis in the south, but the stock is so big that it has not affected the groundwater level yet.

2.3 The irrigation infrastructure

Egypt's irrigation and drainage system is complex. It consists of the Aswan high Dam, eight main barrages, 30,000 km of public canals, 17,000 km of public drains, 80,000 km of mesqas and drains, 450,000 private water lifting devices (sakias or pumps), 22,000 public control structures and 670 public pumping stations for irrigation (Shouhan, 2002).

The basic system of irrigation to the farm level did not change following introduction of controlled (and increased) supplies from Aswan: the tertiary canals (mesqas) carried water in open channels, with the water surface level below ground and farmers pumped from these to irrigate their land. A mesqa might serve 100 ha - some 200 farmers - and the depth to the water level in the mesqa was usually about 1m. The mesqas were part canal, and part storage tank. During an irrigation period water would flow into the mesqa continuously, but farmers would only irrigate during the day. Mesqas generally fed into drains and excess water returned to the system. Gradients are extremely low and flow measurement structures are almost unworkable. Management is largely through controlling levels in channels rather than controlling flow rates.

Pumping from mesqas into the farm channels (marwas) was done using a traditional animal powered device (sakia), and the combination of low power, positive marginal cost of water and plentiful supply ensured that supplies were generally adequate to meet demands in 'old lands'.

As time passed, low-cost powered pumps became available. Farmers quickly adopted these because it reduced the cost of pumping and reduced the time required to take what water they needed. Irrigation continued to intensify and eventually local and occasional shortage developed.

Farmers increasingly frequently face tail-end problems in the branch canal and in mesqas, distribution problems along canals and pollution problems (only some drainage water gets secondary-level treatment). Drainage water, which is re-used for irrigation is not treated, and is often mixed with Nile water to lower pollution concentrations. Farmers are aware of the pollution problem and frequently demand either increased supplies of Nile water, or reduced supplies of drainage water - even though this reduces the total water they receive. Urban sewage water and solid waste thrown in drains are also serious problems.

In response to evidence of local shortages, observation of 'wastage' due to the low field irrigation efficiency, and signs that farmers over-irrigate due to rotational flows, donors (originally USAID) formulated Irrigation Improvement Projects (IIP) in the mid-1990s. Under the IIP, the traditional below-ground mesqas are replaced by elevated concrete-lined channels; rotational flow at the secondary level is changed to continuous flow; and substantial pumping capacity was constructed at the head of the new raised mesqas. In combination, these changes give farmers access to water as and when they want it. Expected benefits were to: save the farmers pumping costs; reduce losses (less leakage and seepage from the unlined mesqas); and to decrease demand as farmers stopped taking 'too much' water. The original expectations of water saving (given the levels of reuse already noted) were always controversial, and it is interesting to note that the project description for the latest World Bank project supporting the IIP (World Bank website) makes no reference to water saving as an objective - focussing rather on improving yields, collective management, cost recovery and pollution management.

Introducing pumps at the head of mesqas, which is done under the IIP without ensuring that the capacity in the distributary channel was sufficient to meet potential demand from all pumping units, will simply move the supply constraint upstream to the distributary canals, so that instead of distribution problems within mesqas, a distribution problem between mesqas is created. It is hard to monitor whether IIP is successful, as it seems that the improved mesqas receive more water than the non-improved mesqas.

Limited field observations show that farmers find the pumps installed at the new mesqa head to be unreliable and difficult to manage collectively. Many farmers have instead installed their own pumps, drawing directly from the distributary, and bypassing the new mesqa. This leads to chaotic and unregulated distribution, higher costs to farmers, and negates the objectives of the IIP. Experiences show that water is not saved under IIP. Furthermore, construction standards for the raised mesqas were not high - and failure of the above-ground system are far more serious than faults in the original, below ground design. Under the IIP farmers take water from a common source by means of pumping into an above ground channel, so that the quantity pumped can be measured. This is, however, often not working. The present attempt at volumetric allocation of water is therefore not feasible to balance supply and demand.

The rationale behind the Irrigation Improvement Project (IIP) was originally to save water. In research in the mid-1990s IWMI questioned this logic, arguing that losses from over-irrigation were in any case usually recovered and used elsewhere, and making more water available to farmers where there had been shortages would tend to increase consumption. Current thinking from those involved in the project support IWMI's position so that the rationale for the IIP is now based on improving the productivity of water and allowing improved local management. This revised approach leaves open the issue that efforts to expand the irrigated area will exacerbate existing shortages, and leaves open the difficult question of management of scarcity (which the Egyptian system was never designed to face).

2.4 Institutions and governance

The Ministry of Water Resources and Irrigation (MWRI) is responsible for the entire irrigation and drainage system above the mesqa level. Local branches of the MWRI manage the irrigation systems. The landowners are responsible to maintain the mesqa and field drains, including removal of weeds and keeping banks in good condition. Water User Associations have been established to control, manage and maintain the tertiary system –the mesqa- with technical support from the Irrigation Advisory Service (IAS), which is part of MWRI. Many of the drains are not working and waterlogging is sometimes a problem.

To improve water management MWRI is keen to formulate, adopt and implement policies that stimulate participation of water users and stakeholders in operation and maintenance of water management systems. They want to delegate responsibility for the branch canals. Currently the ministry uses computerised models for water distribution at the central level. It tries to match rights of each directorate at the regional level. The directorate consists of districts, which distribute water according to availability. A district is about 20,000 hectare and consists of 8-10 branch canals. The schedule of irrigation rotation is known by the farmer (DG of the province makes this kind of strategic decisions and the District Engineer is only responsible for the operational management. There are 3 inspectors that control the District Engineers). The District Engineer co-operates with the water boards. He takes care of the O&M of the canal and controls whether farmers remove weeds from the mesqas. In case farmers do not remove the weeds, the District Engineer will ask a co-operation to do it, but farmers have to pay it.

The water Boards Project (1999-2003) is a Dutch project for the set-up of new Water Boards at branch canal level. The main objective is to develop a viable national policy and legal framework for participatory water management improvement at the secondary level. The outcome will be the formulation of a nation-wide program for the decentralisation of water management in Egypt. Water boards currently help to prioritise problems at the secondary canal level. It seems hard for water boards to continue to exist after the project is finished. It is important that they become self-sufficient in their funding. A legal framework seems required to set-up the required financing structure, i.e. legal entitlements to collect fees. Farmers will only be willing to pay if they benefit from the existence of water boards. Another problem is the participatory management of water scarcity. It is not clear who will define water rights.

There are plans to create Water Boards at district level instead of at branch level. A disadvantage of district level is that it stays far away from individual farmers (less farmer participation) and has less social control -which is a management tool- compared to the branch canal level. Water Boards are responsible for public property (turn over of management), while Water User Associations (WUAs) are responsible for private property (mesqas). WUAs are established in each mesqa and are legal entities by law.

3. Price, costs and value of water ($ 1=6.1 LE)

3.1 Price paid for canal water

Total land tax collections in 2000 came to $ 22 million (LE 133 million) - an average of $ 7.3 ha/yr. Consumptive use of water in agriculture is approximately 50 billion m^3/yr (16,700 m^3/ha) so that the volumetric price of water - if the entire land tax is treated as a charge for water services - which would equate to the same flat rate charge would be $ 0.0004/m^3. This is based on consumptive use - the volumetric rate based on water deliveries (if the on-farm efficiency is indeed 40%) would be $ 0.00016/m^3.

3.2 Costs of water delivery

Cestti (1995) has estimated the share of total O&M costs attributable to irrigation at $ 52/ha. O&M costs are $ 0.003/m^3 on average for water use of 16,700 m^3/ha. Full recovery of allocated costs to agriculture would reduce net farm income of $ 1,200/ha by about 4.5% (Perry, 1996). These data exclude the costs of pumping by farmers because the purpose of these studies was to assess the costs incurred by the state in relation to payments made by the farmers.

More recent estimates of O&M costs - including the cost of pumping at the mesqa level (which was, as an individual, private cost, omitted from the calculations of government O&M expenditures, but under the IIP program becomes a collective cost) suggest total O&M costs of about $ 300/ha, equating to a volumetric cost of water of $ 0.018/m^3 on average for water use of 16,700 m^3/ha. According to Bron (2003) O&M costs of MWRI are $ 131-161/ha in the system and $ 141-166/ha at mesqa and field level (of which pumping is $ 40/ha in IIP areas). The O&M costs incurred by the state are therefore $ 0.01/m^3, which is three times the costs estimated in 1995, among others due to the inclusion now of mesqa level pumping. Taking the total budget of MWRI of $ 0.6 billion (3.7 billion LE) and dividing by the gross water allocation to Egypt of 55.5 billion m^3 results in an comparable average cost of water of $ 0.01/m^3.

3.3 Value of water

The returns to water in Kemry - derived by means of applying a consistent analytical framework to assess the contribution of water to various levels of production - are presented in Table 1 and 2. It shows a cropping intensity of 200%. Maize and rice show a net average return to water delivered of \$ 0.04-0.06/m^3, whereas wheat show a higher return of \$ 0.13-0.15/m^3. The average value of water is about \$ 0.08/m^3.

Table 1 Farm 1 Budget

Crop	Income per ha \$	Crop Area ha	Farm Income \$	Costs \$ Inputs	Costs \$ Labour	Costs \$ Water	Net Income \$	Family Labour Use days	Family Labour Return \$/day	Water Use m^3	Water Return \$/m^3 Gross	Water Return \$/m^3 Net
Rice	1203	1.26	1516	271	133	73	1039	39	26	18,000	0.08	0.06
Wheat	930	1.26	1172	228	78	33	833	19	45	5,400	0.22	0.15
Total/Ave	1067	2.52	2688	499	212	106	1872	58	32	23,400	0.11	0.08

Cropping intensity = 200%, Utilisation of Available Family Labour = 81%, Proportion Family Labour = 37%

Table 2 Farm 2 Budget

Crop	Income per ha \$	Crop Area ha	Farm Income \$	Costs \$ Inputs	Costs \$ Labour	Costs \$ Water	Net Income \$	Family Labour Use days	Family Labour Return \$/day	Water Use m^3	Water Return \$/ m^3 Gross	Water Return \$/ m^3 Net
Maize	750	2.52	1889	603	301	49	935	8	117	21,100	0.09	0.04
Wheat	930	2.52	2345	655	216	65	1409	12	117	10,900	0.22	0.13
Total/Ave	840	5.04	4233	1258	517	114	2344	20	117	31,900	0.13	0.07

Cropping intensity = 200%, Utilisation of Available Family Labour = 83%, Proportion Family Labour = 11%

Lofgren (1995) has estimated a marginal value product of water of \$ 0.02/m^3, compared with an average productivity of \$ 0.08/m^3. A more recent estimate can be derived from national statistics. In 2002 agriculture accounts for 16.8% of GDP of \$ 83.7 billion, which is \$ 14.1 billion. Agricultural production amount \$ 4,700/ha, which is about four times higher than the 1995 figure. Given consumptive use of water in agriculture of 16,700 m^3/ha, the average gross value of water consumed is \$ 0.028/m^3 and the average gross value of water delivered is \$ 0.11/m^3.

Several researches have been conducted to evaluate the value of water for the different crops (Worldbank, 1993, Hussain et al, 1995 and NWRP, 2003). According to NWRP (2003) the net average value of water supplied is \$ 0.07/m^3 and per unit consumed water this comes to \$ 0.10/m^3. These data have different backgrounds and are valid for different years in a period during which crop yields went up considerably. Nevertheless, a general trend can be observed in these data. The high water consuming crops rice and sugar cane give lowest net average return to water consumed \$ 0.03/m^3. The field crops maize and sugar beets give returns in the order of magnitude of about \$ 0.06/m^3. The field crops cotton, beans and wheat have a return of about \$ 0.10/m^3 of water consumed. Vegetable crops such as tomatoes and potatoes give returns of more than \$ 0.16/m^3.

3.4 Discussion of price, costs and value of water

Average returns to water of \$ 0.08/m^3 are 8 times higher than O&M costs attributable to agriculture of \$ 0.01/m^3, which in turn is about 25 times higher than the implicit volumetric price of water \$ 0.0004/m^3. This means that the average returns to water is about 200 times higher than the volumetric price of water. Even if the price of water to irrigators were increased to the full cost of O&M, the effect on demand would be limited because the returns to water are still much higher. This conclusion is identical to that reached by Perry in 1995.

4. Recommended policy instruments

The government's policy of expanding the irrigated area (with the implication of shifting water from 'old lands' to 'new lands') will result in more frequent and widespread shortage of water in the 'old lands'. This raises the question (if we accept the government's policy objective) of how water can be diverted away from long-developed areas with high productivity and demand towards newer less productive areas with minimum negative impact on overall production. Although yields may be lower in the 'new land', returns to water may be higher as often niche crops like early melons are grown, which are sold against high crop prices.

At present, those farmers with access to water use it intensively (and productively). Those with less secure access react by investing less in inputs and in consequence using the available supplies less productively. Shifting water from one area to another should therefore be done in a fashion that minimises the impact of reliability and tail-end problems. The system in Egypt was designed and managed to deliver full crop water requirements. That is why deficit irrigation - a delivery policy of applying less than full requirement - is not proposed. As pricing for water is a sensitive issue, it is recommended to keep the crop-based charge in place.

Measurement of water deliveries in Egypt's larger canals, in very flat terrain is problematic. The IIP provides a basis for measuring deliveries provided farmers take from the single point source and records of pumping are maintained. At present volumetric measurement of pumping is not provided for, and current implementation as seen in the field is chaotic - with individual farmers pumping independently from the larger channels. In present conditions, maintenance of credible records of deliveries at the field level is impossible. This in turn means that volume-based systems of water allocation are presently impossible to enforce and should not be considered until systematic delivery procedures are in place over areas where reduced supplies are planned.

In the future, as demands increase for water supplies to other sectors, balancing supply and demand will be even more difficult. The potential for increasing supplies are limited. The easiest option in management terms is to limit the irrigated area that can be fully served on the basis of available supply. Essentially this is how the system has worked in the past and is the basis for the current design of infrastructure (outside the IIP areas).

If it is decided to pursue a strategy that creates an imbalance between supply and demand, and it is accepted for the present at least that volumetric allocation systems are not feasible, there are three further options:

- First, controls can be placed and enforced on crops such as sugar cane and rice. These can either be strict rules on areas planted or penal water charges that discourage crops.
- Second, seasonal canal closures can be implemented (which is problematic where orchards are significant) to prevent irrigation in the hotter months.
- Third, areas can be rotationally closed on a seasonal or annual basis, so that the problem of shortages is shared equitably among all users, in a transparent and systematic fashion.

The merit of each of these options is that the areas that are irrigated can continue to follow the highly productive and successful system that served Egypt well for centuries.

For water allocation within regions, a gradual Irrigation Management Transfer to local organisations is recommended. Through Water User Associations and Water Boards, users get influence on the service level they require and on interregional water allocation.

To achieve cost recovery an area-based charge is currently used. A crop-based charge can in theory provide incentives to reduce water use of water-intensive crops, but charges would need to be sufficiently high to change the relative profitability between crops. Such high charges will not always be feasible, as the Ministry of Agriculture is rather influential (the fine for rice is currently for instance not enforced). As the level of charges to recover O&M costs will only be 4.5% of farm income, it is likely that these charges will have minimal influence on decisions with respect to the cropping pattern. If water is rationed at the farm level combined with crop-based charges, the result is almost as good as volumetric pricing in including beneficial shifts in cropping pattern towards more water-efficient crops (Perry, 1996).

Crop-based charges seem to be the most proper mechanism for recovering water service cost in 'old lands' as they are administratively manageable and cost effective, whereas volumetric charges could be appropriate in the 'new lands' and Mega projects. A water charge is suggested of \$ 0.008-0.013/m^3. Volumetric charges are less suitable in the 'old lands' in view of the fact that it requires huge investment in measurement devices and personnel, given the fragmented and undersised landownership.

Although cost recovery will be important to shift the financial burden to the water users, this will not be effective for water demand management in agriculture. Water pricing as a measure for water demand management is not recommended as implementation would reduce farm incomes.

5. Conclusions

The challenge that faces managers of Egypt's irrigation system is how to deal with scarcity: the original system, and the operation in the period after construction of Aswan, was based on water supplies generally being enough to meet demand. Scarcity was exceptional and local, and the objective of management was to shift the water around the system according to expected demand rather than manage competing and conflicting requirements. Increasing demand from other sectors; more intensive irrigation in the 'old lands'; and expansion of the irrigated area into 'new lands' has effectively 'created' scarcity - The IIP was originally seen as a means of saving water to alleviate that problem. Experience to date is that water is not saved (indeed consumption probably increases) and management of scarcity is as difficult in IIP areas as in non-IIP areas.

Diverting water away from long-developed areas with high productivity to newer less productive areas should be done in a fashion that minimises negative impact on overall production, i.e. minimise the impact of reliability.

The present attempt at volumetric allocation of water is not feasible to balance supply and demand - as maintenance of credible records of deliveries at the field level is impossible. Any attempt to introduce water measurement would have enormous implications on how the system is operated, the infrastructure needed and the formalisation of water rights. Besides water pricing is a politically sensitive issue in Egypt. It is therefore recommended to limit particular water-intensive crops and the irrigation intensity. There are three options: 1) controls can be placed and enforced on crops such as sugar cane and rice, although controls on rice are currently failing; 2) if water scarcity becomes a significant issue due to expansion of the irrigated area, then either seasonal canal closures can be implemented to prevent any irrigation in the hotter months; or 3) areas can be rotationally closed on a seasonal or annual basis, so that available supply is shared equitably among all users, in a transparent and systematic fashion.

The merit of each of these options is that areas that are irrigated can continue to follow the highly productive system, and they are very transparent. The system in Egypt was designed and managed to deliver full crop water requirements. That is why deficit irrigation - a delivery policy of applying less than full requirement - is not proposed.

Although Egypt's field irrigation efficiency is thought to be inefficient an increase in the local efficiency is of little benefit, as losses in one location are recovered elsewhere. Besides some outflow to the Mediterranean is necessary to meet flushing requirements of the system. Hence improvements in local 'efficiency' within the traditional irrigated areas will not save water at the basin level. However, high local 'efficiency' in the new areas is important as excess deliveries in the new areas will not return to the system for reuse as happens within the Nile valley.

Finally, crop-based charges seem to be the most proper mechanism for recovering water service cost in 'old lands' as they are administratively manageable and cost effective, whereas volumetric charges could be appropriate in the 'new lands' and Mega projects. Volumetric charges are less suitable in the 'old lands' in view of the fact that it requires huge investment in measurement devices and personnel, given the fragmented and undersized landownership.

References

Barakat, E., *Cost Recovery for irrigated agriculture: Egyptian experience*. Article 60 of the proceedings of the Conference in Agadir. Morocco, 15-17 June 2002. Les Politiques d'irrigation considerations micro et macro economiques.

Bron., J., *Water Board Project's.* Technical Report No. 29 (results of baseline study). 2003.

Cestti, R., *Non-agricultural cost recovery: Strengthening irrigation management in Egypt: A program for the future.* International Irrigation Management Institute, 1995.

Davis, R and R. Hirji, (Eds.), *Water resources and environment; Technical Note E.1.* Irrigation and Drainage: Development, The World Bank Washington D C. 2003.

Hussain, Z., D. Seckler and F. Abdel Aan, *Value added, crop choice and agricultural production in Egypt.* SRP, NWRC. 1995.

Lofgren, H., *Water policy in Egypt - an analysis with IFPRI's agricultural sector model. Cairo.* International Irrigation Management Institute. 1995.

Mohamed, A.S., *Water demand management' approach, experience and application to Egypt.* PhD thesis, Delft University of Technology, Delft. 2001.

NWRP, *National water resources plan for Egypt. Facing the Challenge -outline of a draft strategy.* NWRP Discussion Paper No.3. 2003.

Perry, C.J., 'Determinants of Function and Dysfunction in Irrigation Projects and Implications for Performance Improvement'. In: *Water Resources Development* 11 (1995) 1.

Perry, C.J., *Alternative approaches to cost sharing for water service to agriculture in Egypt.* IWMI Research Report 2. 1996.

Shouhan, S., *Farmers' irrigation management practices in Egypt: How farmers cope with changes in water management system in Delta.* Ph.D. Proposal. 2002.

World Bank, *Arab Republic of Egypt Public Sector Investment Review.* Volume 1. 1993.

World Bank, *Egypt at a glance.* www.worldbank.org/data/countrydata/aag/egy.pdf. 2003.

World Bank website, *Integrated Irrigation Improvement and Management Project.* www-wds.worldbank.org/servlet/WDS_IBank_Servlet?pcont=details&eid=)

Appendix D India - Haryana

Abstract
Irrigation water demand in Haryana is well in excess of available canal water supplies, and the groundwater table continues to fall in fresh groundwater areas. The productivity of water use has to be improved in saline groundwater areas. Economic instruments such as volumetric charges or tradable water rights would be difficult to introduce in the present context as the physical infrastructure limits the prospects for more flexible irrigation scheduling. The irrigation system is designed to divide the limited surface water supplies equitably over the command area following a rigid rotational schedule The present system of rationing water provides a sensible and transparent approach to irrigation of small farms under scarcity. A simple initiative would be to maximise the reliability of surface supplies to saline groundwater areas (to minimise recharge) and give fresh groundwater areas more, but less reliable, supplies. It is recommended to define entitlements for groundwater use in fresh groundwater areas. The existing crop-based charge is appropriate, as it recovers costs and gives incentives to allocate water to water-efficient crops.

1. Introduction

Haryana is located on the Indo-Gangetic plain in northwest India with a climate that is arid to semi-arid. It has an area of 4.4 M ha of which 3.8 M ha are cultivable and 2.9 M ha irrigable (GOH, 2004). The population totals 21 M of which 70% is rural. GDP per head is $ 660 (32% above the national average) and has been rising in real terms at up to 3% p.a. Agriculture accounts for 31% of GDP and, along with Punjab, Haryana led India's Green Revolution. Grain yields are some 30-40% above the national average and, with just 1.4% of India's area, this small state provides 30% of the national procurement of wheat and 10% of its rice. Gross sown area in 2001/02 was 6.3 M ha and net sown area 3.6 M ha, giving an overall cropping intensity of 177% and an intensity on irrigated land of about 190-195%. There are three primary sources of water: rainfall, surface water and groundwater:

Annual rainfall averages 545 mm, ranging from more than 1000 mm in the extreme northeast to less than 300 mm in the arid west. Rainfall also varies from year-to-year and from season-to-season. About 80-85% falls in kharif (Jun-Sept), and most of the rest in rabi (Oct-Feb). Evapotranspiration averages about 1,550 mm so that irrigation is a prerequisite for successful cropping most of the time over most of the state.

Surface water comes from the Sutlej via the Bhakra canal system and from the Yamuna via the Western Yamuna system. Sutlej and other Indus allocations are regulated by the Bhakra-Beas Management Board (BBMD), which was created under the 1966 Punjab Reorganization Act. This Act and subsequent agreements govern the state shares in the three rivers (Sutlej, Ravi, Beas) assigned to India by the 1960 Indus Basin Treaty. Haryana has yet to obtain its full share and disputes continue, in particular relating to construction of the Sutlej Yamuna Link (SYL) canal, which would allow access to water from the Ravi and Beas. Yamuna allocations are governed by the Tajewala Headworks Agreement of 1954 as modified by the Punjab Reorganisation Act and other agreements.

Groundwater is abundant on the alluvial Indo-Gangetic plain. Recharge in Haryana has risen greatly as a result of surface irrigation. Brackish groundwater underlies up to two-thirds of the State, an area characterised by poor natural drainage, rising watertables and secondary salinisation. The balance one-third is underlain by fresh groundwater and is characterised by falling watertables since use exceeds recharge by a considerable margin. There are by now some 600,000 tubewells that are predominantly privately owned. Well-owners commonly sell water to their poorer neighbours after meeting their own needs.

It is indisputable that under-watering is pervasive and that, as non-agricultural demands rise, irrigation supplies will come under increasing pressure. Besides water shortages, agriculture is threatened by rising watertables in the western zone (about 52% of the area, Agarwal & Roest, 1996) and by falling watertables in the eastern zone (about 48%). These shares do not fully accord with the distribution of saline and fresh groundwater (see above) and suggest that brackish groundwater is already used for irrigation, presumably mixed with surface water and/or rainfall. In 1997, about 0.42 M ha (10% of the irrigated area) was affected by high watertables, with 0.25 M ha totally waterlogged (GOH, 1998). Another source gives some 0.19 M ha affected by salinity and 0.33 ha by sodicity (Agarwal & Roest, 1996). Interventions that improve on-farm water management, reduce canal seepage, and install drainage could help address these problems. Declining watertables have been accentuated by implicit and explicit electricity and other subsidies.

2. Water problems, policies, infrastructure and institutions

The irrigation management system in Haryana, as in other states in NW India and Pakistan, was formalised under the Northern India Canal & Irrigation Act of 1873 (Eastern Book Co., 1982), based in part on earlier Moghul and British practice. Canals are designed based on 'regime theory' with the aim of distributing suspended silt over the land. Surface supply is intended to be protective (i.e. to spread water over a large area inter alia to guard against famine) rather than productive (i.e. to meet full water demands of a specified irrigable area to maximise yields) (Ministry of Irrigation, 1982; Malhotra 1988; Jurriens et al., 1996). Supply is thus well below potential demand and water is rationed in proportion to irrigable area. Although often referred to as the warabandi system (literally 'fixed turn' system), warabandi is just one component of a complete system of water distribution with the following main features:

Water Allowance

Water is allocated in proportion to land and farmers are free to use their allocation as they wish. In other words the cropping pattern is a response to a pattern of supply (crops to water) rather than supply being a response to a cropping pattern (water to crops).

Delivery capacity (duty) is low, being typically no more than 0.15-0.175 l/sec/ha at the outlet or perhaps 0.17-0.20 l/sec/ha at the head allowing for canal losses (CBIP, 1995).

If given continuously, this satisfies the theoretical crop water requirements of no more than 20-30% of the irrigable land in kharif and of 35-45% in rabi.

Reservoir and River Operations

Reservoir operations are the responsibility of BBMB. Subject to the priority normally given to hydropower and other non-agricultural uses, water is delivered to each irrigation canal headworks in line with the shares of the respective states. The seasonal operational plan is updated at least every three weeks to reflect actual water conditions.

The Main System

The conveyance and distribution system is managed by the Irrigation Department (ID). Main/branch canals are operated with variable flow in response to BBMB allocations and - to a limited extent - demand (see below). Distributaries/minors are either full ON or full OFF, with flow reduction limited at most to 10-15%. When main/branch canals run full (e.g. if river flow exceeds diversion capacity) lower channels also run full.

Distributaries operate in rotation such that the sum of discharges in ON channels equals branch canal discharge allowing for losses. Priorities shift every eight days so that each distributary has an equal chance of being ON. This design has come to be known as the structured design, with the system structured at the head of the distributary (the point below which flows are proportional and canals run full) (Albinson and Perry, 2002).

Adjustable gates on the main/branch canals support variable flow management. ON/OFF gates at the head of each distributary/direct minor allow canal rotation. Below this point, the system is ungated with proportional division at each junction point.

Correct discharges in ON canals are critical to successful operation. Levels are monitored twice daily at key points. If flow at the tail falls below the design, action is taken to increase supply and/or close channels to maintain full supply. Canals are closed annually for maintenance, notably to check offtakes and restore cross sections.

Distribution below the outlet

Outlet capacities are based on duty. If the design duty is 0.15 l/sec/ha, then the capacity of an outlet serving 200 ha is 30 l/sec. To ensure that the stream size is manageable by the farmer (in the range 25-40 l/sec), outlet commands (chaks) are generally limited to between 100-300 ha and typically serve some 50–100 farmers.

All outlets are ungated and run full when the minor is ON. The full flow in the watercourse is allotted to each farmer in turn on a weekly (168 hour) schedule. Turn length is based on farm size. If chak size is 200 ha and duty 0.15 l/sec/ha, then the farmer receives 30 l/sec for 0.84 hours for each hectare of land that he owns. If chak size is 250 ha, then he receives 37.5 l/sec for 0.67 hours for each hectare. Some limited adjustment may be made to these times to account for losses in the watercourse.

The farmer obtains water at the same time each week (the clock keeps ticking). If there is water, he has the right to the full flow. If not, he loses his turn. Equity is ensured by the rotation of distributaries and the flow in the watercourse - if there is one - is owned at all times by a known farmer. The schedule rotates through 12 hours at the end of each crop year to ensure equity in night time irrigation.

The schedule below the outlet is known as the warabandi schedule. Farmers can either arrange this schedule amongst themselves (kutcha warabandi) or request registration by the authorities (pucca warabandi). In Haryana, almost all schedules are registered. It is then an offence to take water out of turn. It is also an offence to exchange or sell turns though this occurs in practice. Farmers maintain the watercourse at their own expense.

Groundwater

Groundwater is unregulated and the landowner has the right to exploit any aquifer lying below the surface of his land. In fresh groundwater areas, this means that the individual farmer has no incentive to limit extractions since others may continue to pump; and in saline areas, the farmer has no incentive to install drainage facilities since this would have to serve the whole locality to be effective. These two examples of 'the tragedy of the commons' are critical to understanding groundwater management.

In its essentials this system has survived since its inception in 1886 despite developments that include: (i) independence and partition, (ii) population growth, (iii) falling farm size, (iv) the Green Revolution, (v) the massive growth of mechanised pumping and (vi) expansion and diversification of an increasingly market-based economy. The system's relative simplicity, transparency and low-cost help explain its robustness (Horst, 1998). Other factors include canal rotation 'which makes it difficult for the farmers to interfere with the 'automatic' distribution by the proportional outlet structures on the distributary' (Jurriens et al., 1996), and lack of ambiguity in the warabandi schedule - the irrigation turn is in effect a property right in water and farmers tenaciously defend their turn. Rationing does not of course meet precise crop water requirements. In Sirsa Circle for the actual cropping pattern and after allowing for rainfall 'canal supply exceeds requirements by about 50 mm (500 m^3/ha) during the winter period and the late summer shortage is about 210 mm (2,100 m^3/ha)' (Agarwal & Roest, 1996). In fresh groundwater areas shortages can l be compensated for by groundwater.

The system does not of course always perform as designed and deliveries may be inequitable both between distributaries/minors and along watercourses (Jurriens et al., 1996). Shortfalls in O&M funds, farmer interference (notably in the outlet)and other factors are all of concern, although farmer interference is more prevalent where farm size and rural power are inequitable or rainfall is higher (or topography and soils are more variable (Berkoff, 1990). On the other hand, some modifications to system operations may even be beneficial (illegal exchange/sale of turns, main system flow adjustments in response to waterlogging/demand etc.).

This said, the system works well relative to other systems in India. Both relative agricultural success and a priori arguments suggest that it is well adapted to local conditions (Berkoff, 1990). Up to the 1950s, western Haryana was notoriously vulnerable to famine, yet now the State provides an astonishing share of India's grain and 'is emerging very fast as one of the leading States in the field of horticulture (though horticulture occupies only) about 5.2 % of cultivable area' (GOH, 2004). The key indicator is the contrast between potential crop intensity based only on surface irrigation (55-75%) and actual intensity (190-195%) utilising all three water sources. This contrast is explained in part by under-irrigation. However, the main reason is the combined use of rainfall, groundwater and sub-irrigation by capillary rise, all of which have been augmented by surface irrigation. Rainfall, which in volume terms may be the largest source, is much less productive without irrigation; groundwater and capillary rise reflect surface water recharge; and brackish water causes less damage - whether from irrigation or sub-irrigation - if used conjunctively with surface water and/or rainfall. The original intention of the system designers may have been to provide protective irrigation but the unanticipated spread of mechanised pumping along with sub-irrigation has led to one of the most productive agricultural systems in India, with high yields and a cropping intensity that approaches 200%.

Crop selection in response to supply (crops to water) means that the farmer rather than the scheme operator is primarily responsible for planning. In effect, the farmer undertakes an implicit linear programming exercise to maximise farm income subject to his assessment of risk. Water rather than land or labour is generally the scarce resource so: 'farmers underirrigate some crops in relation to full potential evapotranspirative demand, because reductions in yield may be proportionally less than reductions in water applied' (Perry and Narayanamurthy, 1998). With regard to risk, rainfall is unpredictable but free; surface water is predictable within limits but incurs a small additional cost; and groundwater is predictable but more expensive. Groundwater and sub-irrigation may also be unusable or damaging. Farmers thus divide their farm into distinct plots on which they plant crops with differing water needs, allocating water between plots in the light of rainfall with the aim of meeting their implicit objective function. Based on field evidence from Bhakra command, Perry and Narayanamurthy conclude that: 'Farmers generally aim to maximise returns to the scarce resource, but due to the uncertainties involved guard against unacceptable risk by reducing the area planted and increasing seasonal water allocations per unit area where supplies are less certain'.

Farmers are intensely concerned for their own welfare and, though there are good farmers and bad farmers, there is little doubt that in general they are equipped to perform this planning exercise. But their perspective is limited to their own interests, and this leads to the tragedy of the commons as described above. In fresh groundwater areas, watertables fall and groundwater irrigation on the current scale is unsustainable over the longer term. In saline groundwater areas, watertables rise and agriculture is threatened in complex ways by water-logging and secondary salinity (Agarwal and Roest, 1996). Any modifications to the present management system must also take these externalities into account (Section 4).

3. Price, costs and the value of water ($ 1=47 Rs)

3.1 Price paid for canal water

Charges for surface irrigation are levied on a crop area basis: that is, rates per ha vary across crops and are charged according to the area irrigated. The ID records crop areas, excluding those that utilise only rainfall and/or groundwater. Areas irrigated from canals are reported to the Revenue Department, which collects what is due as part of Land Revenue. This is incorporated in the general budget and does not directly determine budget allocations for recurrent costs. The general aim is to cover O&M cost, an objective that is almost achieved by the device of assigning only about one third of ID recurrent costs to irrigation, with the rest assigned to non-irrigation users who receive priority at times of scarcity.

There is no explicit volumetric charge, although crop area and type are a proxy for volume. Table 1 shows crop-based charges ($/ha) along with their volumetric equivalents ($/m^3). The average charge can also be estimated from the total revenue derived from irrigation water charges. In 1999/2000, the net area irrigated by canals was 1.44 million ha, generating revenues of Rs. 210 M ($ 4.47 M) (GOH, 2004), equivalent to an average of 145 Rs. or $ 3.1/ha. If total surface water deliveries were about 9.4 Bm3, this implies an average delivery of 6,500 m^3/ha and an average water charge of $ 0.0005/m^3. This is comparable to the estimates in Table 1.

Table 1 Haryana: Water Charges by Crop and Volumetric Equivalents

	Rice (6,800 m^3)		Wheat (4,500 m^3)		Sugar cane (10,000 m^3)	
	$/ha	$/m^3	$/ha	$/m^3	$/ha	$/m^3
Haryana 2000	3.2	0.0005	2.7	0.0006	4.3	0.0004
Haryana 1999	2.4	0.0004	1.9	0.0004	3.1	0.0003

3.2 Costs of water delivery

Surface water costs

Annual recurrent costs of delivering water within Haryana to all users during the period 1996-2000 averaged about USD 18 million per year. Annual deliveries were about 14 Bm3, resulting in an average cost of about $ 0.0013/m^3. This confirms that the Haryana system is low cost which reflects the highly centralised system of management, the relatively small number of control structures, limited staffing requirements, and farmer responsibility for O&M costs below the outlet. This makes no allowance for capital costs, which are very substantial. One third of total costs is allocated to irrigation (i.e. about USD 6 M). In 1996-2000, irrigation received an average volume of 12.9 Bm3/year (92% of the total), implying a cost to irrigation of $ 0.0005/m^3. This was less than one-twentieth of the cost per m^3 attributable to other users ($ 0.0107/m^3, given average deliveries of 1.12 Bm3 and a share in costs of $ 12 M). In return, non-agricultural users receive a more continuous and pre-defined service as well as priority at times of scarcity.

The World Bank-funded Haryana Water Resources Consolidation Project (World Bank, 1994) placed emphasis on cost recovery, requiring first, a clear definition of the costs of system operations, second, political decisions on how costs should be allocated, and third, that charges should be raised to cover O&M expenses over six years. This process was important in clarifying the situation, raising charges and highlighting the extent to which the ID provides water services to other users (drinking water to villages, industrial supplies, supplies to power stations, water to Delhi, and water to other government departments, such as mining, fisheries and forests). Irrigation charges are nevertheless a highly sensitive political issue. In many Indian states, poor cost recovery stems from a combination of both low charges and low rates of collection. In Haryana, however, though rates are low, collection is 90% or more, in part due to collection of water charges as part of Land Revenue. Shortfalls at times of crisis (floods, droughts, pest attacks) are usually offset by collection of arrears in subsequent years.

Groundwater Costs and Charges
Tubewell water is charged by well owners at anything between \$ 0.2-1.6/hour or at a flat rate of \$ 7.0-15.0/delivery/ha irrigated. The wide range reflects not only differing pumping heads, but also the extent to which tubewell-owners seek to recoup capital investment, exploit their monopoly powers, etc (see Section 4). If each delivery amounts to about 1,250 m^3, a flat rate of \$ 7.0-15.0 is equivalent to \$ 0.006-0.012/m^3. This compares to an average quoted fuel cost of about \$ 0.005/m^3. At the lower end of this range it also suggests that charges are largely confined to marginal costs (mainly fuel). Whatever is covered, it is equivalent to ten to twenty times the cost of surface supplies. The ratio would no doubt be lower if electricity was charged at an unsubsidised rate.

Farm-gate Prices
In contrast to domestic water, water for irrigation is an intermediate good, needed to grow crops rather than demanded for itself. The farmer must thus take numerous factors into account beside the cost of water. These include notably farm-gate prices. Procurement prices have risen steadily though this has failed to insulate the Indian farmer fully from the combined impact of rising production, downward trends in world prices and exchange rate effects. Producer prices have even so risen relative to world prices and in some cases are now probably above comparable world levels. This is in sharp contrast to earlier decades, which were characterised by higher world prices, an agriculture that was taxed rather than protected, and a generally stagnant overall economy. Guaranteed markets combined with the extension of irrigation have in particular contributed to the expansion of wheat and rice. These two crops now cover about 50% of the net sown area compared to only 28% in 1970/71 (GOH, 2004). High value horticultural and similar crops have also expanded, although they still account for a relatively small part of the total area Areas under cotton, sugarcane and oilseeds have generally stagnated.

3.3 Value of water

Net Returns
Tables 2 and 3 summarise farm budget estimates for Sirsa District in the western zone. Table 2 is based on information derived from Aggarwal et al (2001) and the World Bank (1998). It assumes that cropping and water use remain the same irrespective of the source of water. This is a simplification since cropping patterns might be expected to adapt to the improved security of supply and, perhaps, the higher costs and volumetric basis of groundwater. Table 3 gives comparable data without distinguishing between surface and groundwater irrigation, based on a survey of 24 farms in rabi 2001-02 and kharif 2002-03 (see Appendix D1). The farms were divided into five categories on the basis of location in the canal system and type of land.

Table 2 Sirsa District: Farm Budgets – Surface Water and Groundwater1

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs: Surface Water			Farm Costs: Groundwater			Net Farm Return	
				Inputs	Labour	Water	Inputs	Labour	Water	Surface	Ground
	$/ha	ha	$	$	$	$	$	$	$	$	$
Kharif											
Rice	327	0.83	270	55	71	2	55	71	32	142	113
Cotton	406	0.60	263	56	23	1	56	23	16	183	169
Chickpea	161	0.34	55	11	23	1	11	23	5	20	16
Rabi											
Wheat	449	2.00	899	165	82	4	165	82	29	647	622
Mustard	443	0.70	295	10	21	1	10	21	14	263	250

1. Year unspecified. Source: Based on information in World Bank (1998) and Aggarwal et al. (2001).

Table 3 Sirsa District: Farm Budgets – Five Farm Types, Rabi 2001/2002 & Kharif 2002/03

	Cropped Area	Gross Farm Return	Farm Costs			Net Farm Return
			Inputs	Labour	Water	
	Ha	$	$	$	$	$
Farm Type 1	16.6	14,380	5,673	1,570	317	6,820
Farm Type 2	6.1	5,109	2,020	435	126	2,528
Farm Type 3	7.6	5,510	2,162	460	106	2,782
Farm Type 4	7.1	3,960	1,987	223	93	1,657
Farm Type 5	7.3	3,974	2,070	423	119	1,361

Farm Type 1: Paddy-Wheat belt, head of canal, normal soils, 4 farms covering a total of 9 ha
Farm Type 2: Paddy-Wheat belt, middle of canal, normal soils, 4 farms covering a total of 3.3 ha
Farm Type 3: Cotton-Wheat belt, head of canal, normal soils, 8 farms covering a total of 5.1 ha
Farm Type 4: Cotton-Wheat belt, middle of canal, normal soils, 4 farms covering a total of 5.9 ha
Farm Type 5: Cotton-Wheat belt, tail of canal, problematic soils, 4 farms covering a total of 5.7 ha

Despite considerable differences between the two sets of data, the tables confirm that water represents only a small part of farm costs, even in the case of groundwater, and that the costs of other inputs (seeds, fertilisers, pesticides etc.) and labour are substantially greater. In the case of the Sirsa scheme, for example, the average shares of inputs, labour, and water are 78, 18 and 4% respectively. Subsidies on other inputs are now limited and their costs approximate to trade-equivalent levels. The labour market is also relatively competitive given seasonal migration from eastern India and, though wages may exceed the opportunity cost of labour, this is becoming less significant as the economy develops. The major distortion in farm costs relative to the economic optimum is, therefore, in respect of irrigation due to low water charges and electricity subsidies.

Apparent Returns to Water

Tables 4 and 5 show net returns per unit of water after allowing for all financial costs, including those of water, for the two sets of farm budget data provided in Tables 2 and 3 respectively. Net returns to water are about $ 0.04/m^3.

Table 4 Sirsa District: Water Use and Net Returns by Crop

Crop	Water Use per ha	Total Water Use per farm	Net Returns Per Farm		Net Returns Per Unit of Water	
			Surface water	Groundwater	Surface water	Groundwater
	m^3/ha	m^3	$	$	$/$m^3$	$/$m^3$
Kharif						
Rice, paddy	6,870	5,700	142	113	0.025	0.020
Cotton	4,835	2,900	183	169	0.063	0.058
Chickpea	2,355	800	20	16	0.025	0.020
Rabi						
Wheat	2,450	4,900	647	622	0.132	0.127
Mustard	3,715	2,600	263	250	0.101	0.096

Source: Based on information in World Bank (1998) and Aggarwal et al. (2001).

Table 5 Sirsa District: Water Use & Net Returns by Farm Type, Rabi 2001/2002 & Kharif 2002/03

Farm Type	Average Water Use	Total Water Use	Net Returns Per Farm	Net Returns Per Unit of Water
	m^3/ha	m^3	$	$/$m^3$
Farm Type 1	9,200	152,700	6,820	0.045
Farm Type 2	9,310	56,800	2,528	0.045
Farm Type 3	6,170	46,900	2,782	0.059
Farm Type 4	5,745	40,800	1,657	0.041
Farm Type 5	7,425	54,200	1,361	0.025

Notes: See Tables 3 and 4.

3.4 Discussion of price, costs and value of water

Care must be taken in interpreting these data. Expressing net farm returns in terms of the net return per unit of water seems to suggest that the profit over-and-above financial costs is wholly attributable to water. However, not only might net returns be similarly attributed to fertiliser or some other input, but this profit represents the farmer's return to land, capital and management after allowing for other costs. If water was to be charged at a rate that equalled apparent net returns per unit to water, returns to land, capital and management would sink to zero (or, in the case of family labour, be no more than the going wage), which is unrealistic. On the other hand, water is a major constraint to increased agricultural production and Tables 4 and 5 suggest an extreme upper limit to the returns to water.

Returns to water are fifty to a hundred times the water charge ($ 0.0005/m^3), implying that water charges would have to rise substantially before they had any significant impact on net farm returns, assuming that the water charge can be made volumetric (see next section). As is to be expected, water use was greater in the paddy-wheat than in the cotton-wheat belt, and net returns per m^3 - at least in the cotton-wheat belt - declined towards the tail and were lower in farms with problematic soils. Tables 4 suggests that net returns per unit of groundwater on the same basis were between two to ten times greater than groundwater charges ($ 0.006 - 0.012/m^3).

The means that surface water charges would have to rise very substantially before they have an impact on water use. In other words water demand at current charge levels under the current system of rationing is almost wholly inelastic. In the case of groundwater, this is less self-evident. Water charges are higher - for the least profitable case, net returns per unit are just double the charge - but water use is discretionary. These issues are discussed in the following section.

4. Recommended policy instruments

Irrigated agriculture will bear the brunt of future water scarcity and the major challenge facing the responsible government agencies is to manage scarcity so as to minimise long-term damage to agriculture, fresh aquifers and soils. Priority objectives are to:

- Increase the productivity of water in the context of declining long-term availability;
- Control over-abstraction of fresh groundwater to avoid decline and salinisation of aquifers;
- Manage saline aquifers so as to reduce/avoid waterlogging and soil salinisation; and
- Finance adequate O&M expenditures along with justified capital improvements.

The above discussion has suggested that water charges have minimal impact on surface water use. The system delivers a rationed supply that is sufficient for a limited part of the irrigable area. Since charges are well below the value of water to the farmer, there is no reason for him to reject any of his share since water can almost always be profitably used to meet the needs of irrigated crops, supplement rainfed crops, moderate under-watering, save on pumping costs or leach salts from the land. Only if land is waterlogged or flooded has the farmer reason to reject his share and the ID then often closes higher canals so as to alleviate problems that typically go well beyond the individual farmer. Instances where water cannot be profitably used are thus few and excess water in any case may do no harm. Far from rejecting his turn, therefore, the farmer resolutely defends it.[1]

Considerations in groundwater are very different. Not only are the charges made by well-owners (much) higher than for surface water but a decision whether or not to turn on a pump is discretionary and does not prejudice access to the resource at a later time. The amount of fresh water extracted is thus a function of demand and not availability. In conjunctive use areas, surface water is a relatively stable if limited base supply; rainfall is variable and uncertain but free; and groundwater can be fine-tuned to 'optimise' net returns after exploiting other sources. That fresh groundwater is over-pumped reflects the pattern of financial incentives, with richer farmers better able to adjust to falling watertables than poorer farmers. If falling watertables adversely affect water quality, then the resource may be lost and this of course then becomes the decisive concern.

[1] If the farmer cannot defend his turn - if rural power is distributed inequitably or law-and-order breaks down - then the system is weakened. Persistent theft by head-enders can also wear the tail-ender down even under normal circumstances. Moreover, if rainfall is higher and the design supplements rainfall in *kharif* over the full irrigable area, or conditions are more variable than in Haryana, then there will be more instances when the individual farmer will want to reject water and this again tends to undermine this management system (Berkoff 1990).

In other words, so long as fresh groundwater is freely available, groundwater is provided on a volumetric basis and the amount demanded broadly optimises farmer net returns subject to anticipated farmgate prices, input costs, cross-elasticities and numerous other factors. Groundwater use in an imperfect and variable way thus reflects farmer willingness to pay. If conditions change (expected farmgate prices rise, electricity subsidies are withdrawn etc), the outcome is different. Net farm returns over-and-above financial costs (including water costs) are the farmer's return to land, capital and management and cannot be attributed to water as such. That the groundwater charge is so variable reflects variable spatial, temporal and farm conditions and numerous market imperfections. Even if extractions were to be effectively regulated, for instance to account for the externality costs associated with over-pumping and/or salinisation, the market would adjust to the new conditions with the price determined by the property rights created rather than by the current conditions of open access.

Surface irrigation is thus supply-driven and consumption is largely unaffected by water charges, while groundwater irrigation - no matter how imperfectly - is demand-driven and consumption is a function of alternative water sources (rainfall and surface supplies) and (imperfect) market incentives. Given this background, what is the potential role of pricing policy in meeting the above objectives? The discussion is in two parts: (a) policies that require restructuring of the infrastructure; and (b) policies that can be implemented with the present infrastructure.

a) Policies Requiring Restructuring of the Infrastructure

Volumetric charges are often advocated as a mechanism for reducing water use and increasing output per unit of water. They require an infrastructure that can provide differentiated water supply and measurement at the point of sale. In the case of Haryana, they would thus require that the supply-based surface system (including the warabandi schedule) be replaced by a demand-based system that allowed water to be delivered in response to willingness to pay. To be effective, demand at the point of sale would have to be elastic with respect to price. At the theoretical limit, the charge would be ideally set such that demand and supply are brought into balance. For surface water in the Haryana context, volumetric charges could be levied at three possible levels: head of the watercourse, head of the minor/distributary and the farm.

Irrespective of how far differentiated supply is taken down the system, water rates must be sufficiently high to elicit a response if they are to impact on water use. The increase required is in itself politically and socially infeasible. But there are more fundamental objections to volumetric pricing to the farmer. The present system is stable, simple and cheap to operate and this has major advantages for large schemes in developing countries (Horst, 1998). Moreover, the system already provides powerful incentives limiting water use and maximising output - surface water use per hectare is already low and by Indian standards productive. This is so even if groundwater is saline. Where it is fresh, applications at the margin are charged on a volumetric or quasi-volumetric basis from groundwater. Farmers operate in real time, adjusting groundwater use in response to rainfall, surface supplies and financial incentives. Quite apart from the costs and risks of restructuring the delivery system, and replacing a supply-based system by a demand-based system, it is hard to imagine that volumetric pricing could be more successful.

Levying a volumetric charge at the head of the watercourse, minor or distributary is a less clear cut issue and in some circumstances there may be a case for creating WUAs and/or organisations operating at the distributary or minor level. If WUAs and/or autonomous agencies are to be financially viable, they may limit demand in response to even moderately-enhanced charges and may be willing to sell allotted shares if a market develops at this level. Being closer to the farmer, they may also be in a position to influence on-farm use even without volumetric charges to the farmer. However, the rationale for this has more to do with cost recovery and effective O&M than it has with enhancing the productivity of water -and where the system is functioning relatively well - as in Haryana – the uncertainties and risks are almost certainly unacceptable.

Account must also be taken of falling watertables, waterlogging and salinity. Declining watertables raise costs and disadvantage poor farmers. More importantly, they can affect quality since deeper aquifers are typically more saline than shallow aquifers. Rationing of surface water other things being equal has slowed the process of waterlogging and salinity. Even so, a demand-based system that matched supply and demand, coupled with an increase in surface charges, could in principle slow this process further

b) Policies within the present infrastructure

If full volumetric water pricing of surface supplies is ruled out, what potential is there for modifying the present water charge system to reflect quasi-volumetric considerations? Possibilities can again be considered at three levels: main system, watercourse and the farm.

Main system rotation is equitable in terms of irrigable area. Given the homogenous character of an alluvial plain and equitable holding size, this also has the merit of transparency. Even so, differences between sub-commands - notably between fresh and saline areas but also in terms of rainfall, cropping patterns and other factors - could be reflected in differential schedules (Narayanamurthy, 1985). To a limited extent this already happens since the ID closes canals where waterlogging or flooding is acute irrespective of 'equity' considerations. One option would be to devise rotations that provide reliable but lesser supplies to saline areas (to ensure security and minimise recharge); and less reliable but greater supplies to fresh areas (since they already have security and excess deliveries can be recaptured by pumping). Another option would be to devise schedules to meet differential demands of the predominant cropping pattern e.g. differentiating between paddy-wheat and cotton-wheat (Narayanamurthy op cit). This has the potential for bias and would tend to erode transparency. Any new schedule would thus need to be articulated in a straightforward manner.

The distinguishing feature of distribution within the watercourse is the warabandi schedule. Farmers have strong incentives to defend their turns and this is a major strength of the system. Trading beyond the watercourse implies a fundamental restructuring of the delivery system (see above) but trading along a watercourse is quite possible and undoubtedly occurs despite being an offence. -Losses in the watercourse- result in more water being delivered at the head than the tail so that sale of tailender turns to headenders adds to the surface water available (and incidentally may well be a factor in the inequities recorded in watercourse studies) (Jurriens et al., 1996). Farmers in any case differ in their resources, skills and wants, which leads to trades that may increase total welfare. Allowing trades along the watercourse is a market mechanism that could in principle increase productivity although it impacts on patterns of groundwater recharge and runs the danger of weakening the traditional and accepted system.

Differential crop charges imply a quasi-volumetric element at the farm level. Increased differentials and penal rates for crops that utilise large amounts of water could in principle make this approach more effective However, cropping patterns cannot always be changed - paddy may be the only feasible crop in higher rainfall and waterlogged areas - and political objections would still have to be faced. A more interesting suggestion is made in the Indo-Dutch report. If water charges were to be based on the authorised water delivered to the farm rather than on the measured crop areas, they conclude that irrigated areas in saline regions - presumably in kharif - could increase from 50% to 85%. Much of the rainfed part of the farm would be converted to partial irrigation and the annual rise in saline watertables might be slowed - (recharge would decline due to underwatering and greater evapotranspiration). As a result, waterlogging problems 'can be postponed by 5 to 10 years' (Agarwal and Roest, 1996). Of course, farmers even now irrigate crops on that part of their farm that they claim is rainfed and subsequently mislead or collude with ID staff. Moreover, the act of measuring areas - indeed the whole land revenue tax process - contributes much to conserving the delivery and land tenure systems. Nevertheless, this proposal might receive further consideration.

5. Conclusions

Surface irrigation water in Haryana is distributed in proportion to holding size irrespective of soil type, crops grown, groundwater conditions or climatological factors. The amount delivered is sufficient in itself for no more than 20-30% of the irrigable land in kharif and of 35-45% in rabi, leading to widespread under-irrigation. Surface supplies are supplemented by (variable) rainfall and - if water is fresh - by groundwater pumping so that cropping intensities are much higher than would be possible based just on surface supplies. Nevertheless, water remains a major constraint on agricultural output and this is likely to intensify as non-agricultural demands grow. Agricultural production is also threatened by rising watertables in saline groundwater areas and falling watertables in fresh groundwater areas.

Effective rationing of surface supplies provides powerful efficiency incentives in water use, both directly and as pumping responds to variable rainfall and regular surface deliveries. This has been reflected in a remarkable growth in agricultural production despite constrained surface supplies. Moreover, the combination of main system rotation and warabandi below the outlet has proven robust and has demonstrated important advantages in terms of equity, transparency, social acceptance and low transactions costs. A shift from an accepted supply-based system to a demand-based system and volumetric pricing would involve major reconstruction of the physical infrastructure and a fundamental reform of accepted institutions and practices. Moreover, the increase in the level of water charge needed to have a significant impact on water use would almost certainly be politically and socially unacceptable. Thus, while in principle it might lead to a more responsive irrigation system, it is inconceivable that this could justify the massive costs and risks involved in making such a change.

More modest reforms of the supply-based system might include revised main system schedules, greater differentiation in area-based water charges, or replacement of area-based water charges by charges based on the water delivered during a warabandi turn. Main system schedules could in principle be modified to respond to soil or cropping conditions, for instance to provide more reliable but less abundant supplies to saline areas and vice versa, or to respond to the predominant cropping pattern in different areas. Water charges are presently collected along with land revenue and are based on the area of each crop irrigated by canal water. Charges are low but collection is relatively efficient and makes a reasonable contribution to meeting recurrent costs. Rates could be increased and the levels for different crops could be further differentiated to encourage planting of water-efficient crops. Alternatively, crop-based charges could be replaced by a charge dependant on the authorised water delivered during a warabandi turn, leaving the farmer to decide how best to allocate water on his farm.

Any such reforms need to be introduced cautiously given the risks associated with many modification of the current accepted system. They would also at best have a modest impact on the long-term problems of falling watertables in fresh groundwater areas and waterlogging and secondary salinity in saline areas. Regulation of groundwater use represents a formidable challenge given the huge number of wells and well-owners. In the absence of an effective regulatory system, watertables will continue to decline until this is limited by rising pumping costs or deteriorating water quality. Waterlogging in saline areas can at best be slowed by reforms of the type discussed above. The only ultimate long-term solution would be costly investments in drainage and reclamation programmes.

References

Agarwal, M.C. and C.J.W. Roest (Eds,), *Towards improved water management in Haryana state.* Final report of the Indo-Dutch Operational research Project on Hydrological Studies, Haryana Agricultural University, Hisar, International Institute for Land Reclamation and Improvement (ILRI) & DLO Winand Staring Centre for Integrated Land, Soil and Water Research, Wageningen. 1996.

Aggarwal, P.K., R.P. Roetter, N. Kalra, H.Van Keulen, C.T. Hoanh and H.H. Van Laar, *Land use analysis and planning for sustainable food security* (with an illustration for the state of Haryana, India). 2001.

Albinson, B. and C.J. Perry, *Fundamentals of Smallholder Irrigation: The Structured System Concept*. IWMI Research Report No 58, Colombo. 2002.

Berkoff, D.J.W., *Irrigation Management on the Indo-Gangetic Plain*. Technical Paper No. 129. World Bank, Washington D.C., 1990.

Central Board of Irrigation and Power, *Improving Canal Water Delivery Performance - Some Approaches*. Publication No. 246. June 1995.

Eastern Book Company, *The North India canal and Drainage Act, 1873* (along with State amendments and short notes). Lucknow. 1982.

GOH, *Management of waterlogging and Salinity Problems in Haryana*. Master Plan', Prepared by High Level Expert Committee Government of Haryana. December 1998.

GOH, *Economic Survey of Haryana 2003-2004*. Planning Dept., Government of Haryana. 2004.

Horst, L, *The Dilemmas of Water Division' Considerations and Criteria for System Design.* IWMI Colombo & ILRI, Wageningen University. 1998.

Jurriens, M., P.P. Mollinga and P. Wester, *Scarcity by design; Protective irrigation in India and Pakistan.* Liquid Gold Paper 1, ILRI. 1996.

Malhotra, S.P., *The Warabandi and its Infrastructure*. Publication No. 157. Central Board of Irrigation and Power, 1998.

Ministry of Irrigation, *Manual on Warabandi in Irrigation Projects*. Government of India. New Delhi. April 1982.

Narayanamurthy S.G., *Methods for Improving Canal Regulation in Northwest India, using the example of the Bhakra Scheme.* World Bank, New Delhi Office, December 30, 1985.

Perry C.J., and S.G. Narayanamurthy, *Farmer Response to Rationed and Uncertain Irrigation Supplies*. Research report 24. IWMI, Colombo, 1998.

Van Dam, J.C. and R.S. Malik (Eds.), *Water productivity of irrigated crops in Sirsa district, India: Integration of remote sensing, crop and soil models and geographical information systems.* 2003.

World Bank, *Haryana Water resources Consolidation Project.* Staff Appraisal Report No. 12813-IN, World Bank, March 3, 1994.

World Bank, *India Water Resources Management Sector Review - Initiating and Sustaining Water Sector Reforms.* Report no. 18356-IN. 1998.

Appendix D1 Overview of outcome of the spreadsheets

The returns to water in Sirsa district of Haryana State in India were studied (see Figure 1 below), using data on 24 farms. Eight farmers were selected from Ottu Feeder in the Paddy-Wheat belt (4 from Ram Pur Their and 4 from Sangatpura in eight Burji Ottu villages) along with 16 farms from Kasumbi Distributory in the Cotton-Wheat belt in six villages (4 from Fulkan, 3 from Kotli, 2 from Kanvar Pura, 1 from Ding, 1 from Kasumbi and 5 from Ban Mandori). These 24 farmers were divided into five farm categories on the basis of location in terms of the canal water source outlet and type of land. The data required for the AGWAT spreadsheets pertaining to Rabi 2001-02 and Kharif 2002-03 were collected from each respondent through personal interviews using structured questionnaires. The results are summarised in Tables D.1-D.5. It is important to note that the data are based on an exceptional year, with very low canal water availability and rainfall.

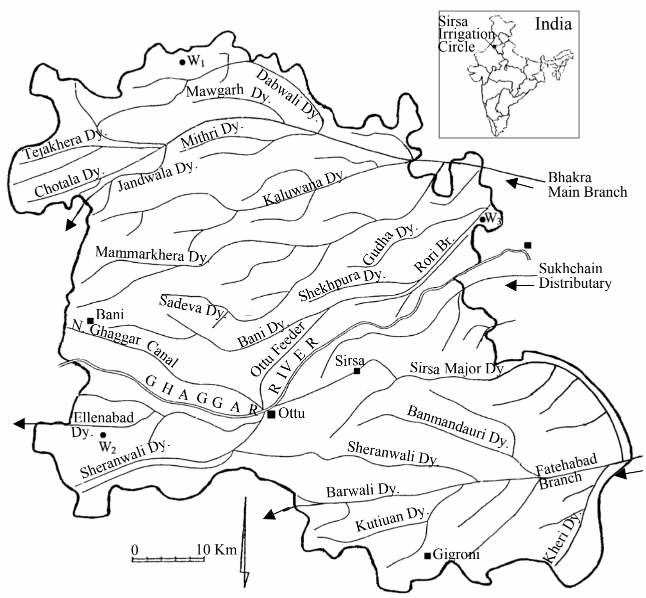

Figure 1 Location of the Sirsa Irrigation Circle showing the canal network.

Source: Van Dam and Malik, 2003.

Farms 1 and 2 experienced a shortage of family labour during the peak months of July (transplantation of paddy), October and November (due to harvesting of paddy, sowing of wheat crops and peaking of cotton crop on Farm-1). Both farms also experienced insufficient supply of canal water throughout the year, compensated for by groundwater pumped from tubewells. Highest net returns were found to be from mustard; net returns per cubic meter of water were smaller on Farm 2 than on Farm 1. Farms in the Cotton-Wheat belt experienced a shortage of canal water in the months of February, March, August, September and October. The cotton crop was more remunerative on Farm 3 than on Farms 4 and 5. The net returns were highest for Guar.

Table D.1 Farm Type 1 (Paddy-Wheat belt, head of canal, normal soils, 4 farms; 9 ha)

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs Inputs	Farm Costs Labour	Farm Costs Water	Net Return	Water Use	Water Total Use	Water Net Return
	$/ha	ha	$	$	$	$	$	m^3/ha	m^3	$/$m^3$
Kharif Rice	894	7.88	7,046	3,256	1,155	233	2,403	13,782	108,600	0.02
Cotton	580	0.36	208	112	28	6	62	8,611	3,100	0.02
Rabi Wheat	857	8.24	7,067	2,293	385	78	4,313	4,927	40,600	0.11
Mustard	655	0.09	59	13	2	1	43	3,333	300	0.15
Total	868	16.6	14,380	5,673	1,570	317	6,820	9,200	152,700	0.045

Table D.2 Farm Type 2 (Paddy-Wheat belt, middle of canal, normal soils, 4 farms; 3.3 ha)

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs Inputs	Farm Costs Labour	Farm Costs Water	Net Return	Water Use	Water Total Use	Water Net Return
	$/ha	ha	$	$	$	$	$	m^3/ha	m^3	$/$m^3$
Kharif Rice	880	3.04	2,675	1,188	366	96	1,023	13,816	41,800	0.03
Rabi Wheat	801	3.04	2,434	831	69	29	1,505	4,934	15,000	0.10
Total	840	6.1	5,109	2,020	435	126	2,528	9,310	56,800	0.045

Table D.3 Farm Type 3 (Cotton-Wheat belt, head of canal, normal soils, 8 farms; 5.1 ha)

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs Inputs	Farm Costs Labour	Farm Costs Water	Net Return	Water Use	Water Total Use	Water Net Return
	$/ha	ha	$	$	$	$	$	m^3/ha	m^3	$/$m^3$
Kharif Rice	499	0.10	51	36	5	3	7	10,000	1,400	0.01
Cotton	792	2.96	2,342	918	228	62	1,134	9,460	27,700	0.04
Rabi Wheat	772	3.37	2,598	974	198	32	1,393	4,154	13,600	0.10
Mustard	443	1.17	519	234	29	10	247	3,419	4,100	0.06
Total	725	7.6	5,510	2,162	460	106	2,782	6,170	46,900	0.059

Table D.4 Farm Type 4 (Cotton-Wheat belt, middle of canal, normal soils, 4 farms; 5.9 ha)

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs Inputs	Farm Costs Labour	Farm Costs Water	Net Return	Water Use	Water Total Use	Water Net Return
	$/ha	ha	$	$	$	$	$	m^3/ha	m^3	$/$m^3$
Kharif Cotton	659	2.53	1,665	1,002	116	56	492	10,040	25,400	0.02
Guar	410	1.00	410	130	8	3	270	200	200	1.74
Rabi Wheat	571	2.65	1,512	700	88	27	697	4,491	11,900	0.06
Mustard	423	0.88	373	156	12	7	198	3,750	3,300	0.06
Total	561	7.1	3,960	1,987	223	93	1,657	5,745	40,800	0.041

Table D.5 Farm Type 5 (Cotton-Wheat belt, tail of canal water, problematic soils, 4 farms; 5.7 ha)

Crop	Gross Return	Cropped Area	Gross Return	Farm Costs Inputs	Farm Costs Labour	Farm Costs Water	Net Return	Water Use	Water Total Use	Water Net Return
	$/ha	ha	$	$	$	$	$	m^3/ha	m^3	$/$m^3$
Kharif Cotton	644	3.12	2,009	1,085	256	81	586	11,795	36,800	0.02
Guar	513	0.79	407	112	10	2	283	253	200	1.80
Rabi Wheat	476	3.12	1,484	828	152	34	470	5,192	16,200	0.03
Mustard	326	0.23	74	45	4	2	22	4,348	1,000	0.02
Total	533	7.3	3,974	2,070	423	119	1,361	7,425	54,200	0.025

Appendix E Indonesia - Brantas River Basin[1]

Abstract
The increasing demand for water and limited degree of cost recovery for irrigation water delivery are important challenges for policymakers in Indonesia. To meet the increasing demand for water, it is important to reduce water use in irrigated paddy cultivation, long the dominant consumptive user, and to divert water away from agriculture to domestic and industrial sectors. Reducing water use in irrigated agriculture can be achieved through various means, including rationing, user management, and water markets. The appropriate method depends on the unique situation of each basin. In the Brantas Basin in East Java, rationing is already practiced, but often leaves the non-licensed, (non-paying) irrigators with insufficient supplies. Moreover, very low irrigation service fees hamper ongoing water sector reforms, which seek to strengthen the capacity of local institutions to co-manage water resources. In the Brantas Basin the average value of water in the production of important irrigated crops substantially exceeds estimated water supply costs and current ISF. Increased water use fees would impose a substantial burden on farm economic welfare, while water savings would be relatively modest. Therefore, to conserve water and enhance the financial autonomy of irrigators alternative management systems are proposed, including enhanced crop management, such as the System of Rice Intensification and a water brokerage mechanism.

1. Introduction

In 2002 Indonesia had a population of 211.7 million - growing at 1.3% per year - of which 57% lived in rural areas. Agriculture accounted for 17.5% of GDP, and gross net income per capita was $ 710 (World Bank, 2003). Although Indonesia is a vast archipelago with a total land area of 1.9 million km2, half of the population is concentrated on the island of Java with an area of only 132,500 km2 due to the island's extremely favourable climate and soils. About 64% of Java (and Bali) falls within moist rainfall zones (1,500-3,000 mm per year) and 30% are wetter (3,000-5,000 mm per year), whereas potential crop evapotranspiration rates are around 1,400 mm per year.

Java has 3.3 million ha of irrigated area, 43% of Indonesia's total irrigated area. Almost 60% of this area is served by either technical or semi-technical irrigation systems. Availability of renewable water in Java is only 1,540 m^3/person/year, whereas the Indonesian average is 15,600 m^3/person/year. In Indonesia, roughly 93% of utilised freshwater resources are withdrawn for irrigation, 6% for domestic and 1% for industrial use.

[1] This case study is based on Rodgers (2004). The Role of Economic Incentives in Promoting Improved Water Use Efficiency in Indonesian Irrigated Agriculture.

Paddy is the most important irrigated crop. More than half of all paddy produced in Indonesia is harvested on Java, and Javanese yields are around 15% higher than the Indonesian average reflecting the concentration of technical and semi-technical irrigation systems, favourable soils and climate, and the historical accumulation of experience in paddy cultivation.

Harvested paddy area expanded steadily between 1951-2000, actually accelerating, particularly during the final two decades of record. Yields, by contrast, were stagnant during the decade of the 1950's, took off in the 1960's and grew rapidly through the 1970's and 1980's, contributing almost 70% of total output growth during the period 1961-1990. However, yield growth stagnated in the 1990's, suggesting a combination of transient adverse climatic conditions, impacts of recent declines in irrigation and agricultural research investments, and that the gains from the 'green revolution' crop improvement programs of the 1960's-1980's are now nearly exhausted. The share of rice output growth during 1969-1990 explained by public investment in research, extension, and irrigation was estimated at 85%, of which extension accounted for 33% of output growth, followed by irrigation at 29% and research at 23% (Rosegrant et al., 1998). A more recent study estimated that between 1985 and 2000, expanded irrigation and improvements in its quality accounted for about 23% of rice output growth in Indonesia (Rodgers, 2004).

Irrigated paddy cultivation, long the dominant abstractive and consumptive user of water, is facing increased competitive pressure from other sectors. These include municipal and industrial users, aquaculture, as well as the natural environment via demand for waste dilution flows. Investment in water supply augmentation, specifically in dams, weirs and related structures, remains an important strategy to counteract increased pressure on water resources. However, opportunities for economically rational investment in large-scale physical infrastructure are increasingly scarce on the densely settled and extensively developed island of Java. Therefore, the focus of study here is the role economic instruments, including water charges and tradable water rights, as well as enhanced crop management systems can play to better manage the demand for increasingly scarce water in agriculture.

The document is organised as follows: Section 2 outlines the water problems, policies, legal and institutional frameworks for water management and irrigation infrastructure in Indonesia. Section 3 examines important components of the water demand management framework: the price, cost and value of water in irrigated agriculture. Data are presented for the Brantas Basin in East Java. In Section 4 alternatives to volumetric irrigation water pricing, including recent research on water-saving techniques and the water brokerage mechanism are reviewed. In Section 5 some concluding remarks are drawn.

2. Water problems, policies, infrastructure and institutions

2.1 Water problems and policy objectives

Currently there is a low rate of utilisation of renewable freshwater resources in Indonesia, mainly due to 1) the highly seasonal distribution of precipitation and resulting runoff, 2) the steep and short topography of catchments, and 3) the limited surface and groundwater storage capacity. The same topographic factors limit the number of suitable sites for dams capable of storing large shares of annual discharges. As a consequence, much of the wet-season runoff remains unused, while dry-season flows are often insufficient to meet demand. This situation is exacerbated by ongoing deforestation and related degradation of upper catchment areas, in particular on Java.

A recent study of global food production and water use (Rosegrant et al., 2002) projects that total water consumptive demand in Indonesia will increase by 11.7 BCM over the period 1995-2025, of which irrigation will comprise 7%, and municipal, industrial and livestock demand 93%. These projections indicate that the irrigation sector's relative share of total consumption will decline. This is also reflected in Java's ongoing net decline in irrigated area. In East Java alone, 102,000 ha were taken out of agricultural production during 1994-1999 as a result of competition for both land and water resources. These land use conversions are largely due to urban-industrial development and take place without government interventions. Moreover, agriculture is increasingly diversifying on Java. In particular, maize area for animal feed has increased rapidly in East Java, which helps to reduce pressure on irrigated paddy. In spite of these trends, irrigation will remain the dominant water-using sector in Indonesia for the foreseeable future. To meet the increasing urban demand for water, it is important to reduce water use in irrigated rice production, which can be achieved through various means, including administrative or agency allocation of water, for example, in the form of quotas, user management of water, and water markets, based on secure water use rights for irrigators.

Moreover, while returns to irrigation investment have been high in the past, cost recovery of these investments has been low, hampering new, more expensive developments, as the most suitable locations have been exhausted. Lack of even O&M recovery also stands in the way of irrigators taking on greater control and management functions of irrigation systems under the current decentralisation and water sector reform efforts.

The reallocation of water and increase in water productivity are therefore important policy objectives. Another policy objective that needs to be addressed is the limited degree of cost recovery.

2.2 Existing policy instruments

Currently a de facto quota system is in place. Farmers in the Brantas basin, for example, know that most of the irrigated crops in the second dry season are considered unauthorised, that is, they will not necessarily receive additional water to maintain their crops. A quota system can work, as farmers know in advance what how much water they can expect, and thus can adapt their cropping plans accordingly. However, farmers are currently not compensated if they receive less water as they do not have a license and are not paying for bulk-water deliveries, contrary to other use sectors. This was particularly visible in the 2003 drought when farmers in the Citarum basin had to watch water passing by in full canals sent to Jakarta - they had no recourse for the imposed quota/rationing system, apart from social unrest/protests.

2.3 The irrigation infrastructure

KIMPRASWIL (Ministry of Human Settlements and Regional Infrastructures), acting through district and sub-district offices of the Water Resources Service (Dinas Pengairan), is responsible for the construction and maintenance of primary and secondary irrigation canals, and controls distribution up to the first 50 meters of tertiary canals in technical systems. Farmers, local government/organisations are responsible for O&M of tertiary canals and field channels.

KIMPRASWIL classifies irrigation systems as technical, semi-technical and village systems. Technical systems have permanent canals, control structures and measuring devices, and drainage networks are distinct from canal networks. Systems usually consist of main, secondary and tertiary canals, the latter delivering water to a tertiary block (the basic water management unit). Semi-technical systems have permanent canals, but few controls or measuring devices, and the government generally controls only the source and main canal. The distinction between technical and semi-technical systems is not always clear. A typical surface irrigation system network is illustrated schematically in Figure 1.

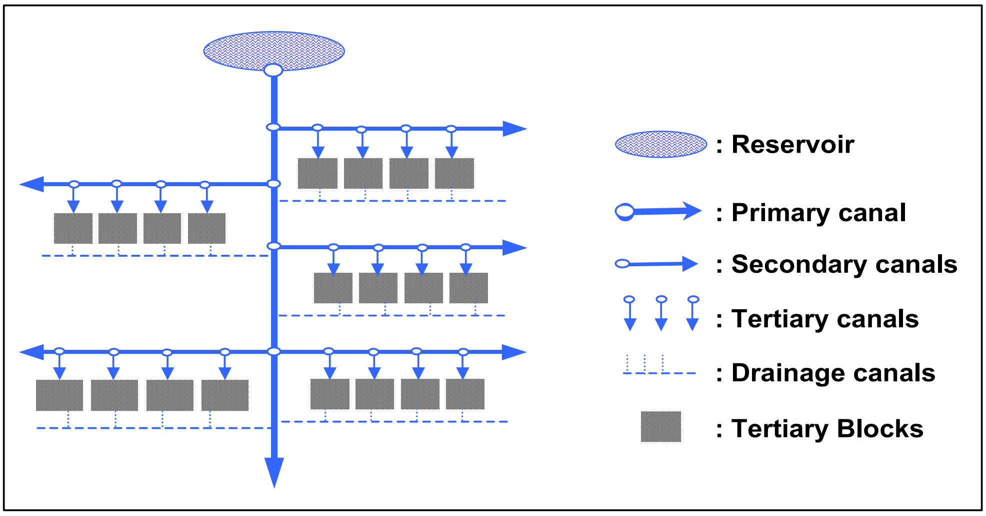

Figure 1 Standard Surface Irrigation System Network

Village systems are usually smaller than technical or semi-technical systems (< 50 ha), have few permanent control and distribution structures, and are usually farmer-managed. The performance and effectiveness of village systems are not necessarily inferior to those of technical or semi-technical systems, since in each instance the system efficiency will reflect both the care with which infrastructure is maintained and the skill with which it is operated. The reliability of water supply is typically higher for technical and semi-technical systems.

While the rainy season in Indonesia typically supports one primarily rainfed crop, technical and semi-technical systems permit, on average, around 1.8 crops per year, and village systems between 1.6 and 1.7 crops, whereas other types of systems, for which dry season water supplies are not as reliable, average only 1.1 to 1.2 crops per year.

Local topography strongly influences the layout of plots and the hydrology of paddy cultivation. In areas of low topographic relief, plots are often laid out in long, narrow configurations with axes at right angles to the tertiary canals. This promotes equity in allocation, minimizing advantages that would otherwise accrue to plots immediately adjacent to canals. In areas of steeper topography, fields are arranged along contours as terraces, and water moves down grade from field to field, typically through orifices or breaches in the bunds separating up-slope from down-sloping plots. Only the uppermost plots have direct access to canals, in contrast to low-gradient layouts that attempt to link as many plots as possible.

The distribution of irrigation water from the source (river, reservoir) down to individual rice fields can be summarised as follows. Water released to the river from the reservoir enters primary canals at diversion structures (weirs, barrages) and is subsequently partitioned to secondary canals and tertiary canals via gates. Tertiary canals convey the water to blocks of irrigated fields, varying in size from 10 to 300 hectares depending upon topography and system design. In order to reach land parcels located in the middle of tertiary blocks or far from tertiary canals, farmers organise into groups to develop field channels. In most technical and semi-technical systems, primary, secondary and tertiary canals are paved. Field channels are not lined since they are located within a tertiary block, so that seepage is largely utilised.

2.4 Institutions and governance

The range of demand management policies and strategies available to policymakers, as well as the effectiveness of such strategies, is largely defined and constrained by the laws and institutions (both formal and traditional) that govern and regulate access to, allocation, and use of water resources.

Water Sector Legislation and Reforms

During the first 25-year phase of Indonesian water resources development policy, (PJPI - 1969-1994), the primary emphasis was placed on the irrigated agricultural sector around the objective of achieving national self-sufficiency in rice production (which was temporarily achieved in 1984). Investment policy focused initially on the rehabilitation of large and medium-scale irrigation systems, subsequently on the construction of new systems and on improvements in system operation and management. In the second water resources development plan (PJPII - 1994-1999), emphasis shifted to sustainable water resources development and, in particular, to the holistic and integrated management of water resources at the river basin scale for multiple purposes.

Currently, no single model of water resources allocation is universally applied throughout Indonesia, as statutory law dominates in certain settings and traditional law prevails in others, exemplified in the Balinese subak system. Certain broad principles of water management clearly apply, however. According to Article 33 of the Basic Constitution, natural resources are governed by the State in public trust for the people. Law No. 11 (1974) on water resources additionally establishes water allocation priorities for drinking water, followed by agriculture, and then energy. It further states that direct beneficiaries, including corporations and associations, participate in bearing the cost for water resources O&M activities, along with central and local governments. This is an important provision with respect to irrigating farmers and water users' associations (WUAs), which may or may not meet the strict definition of corporations and associations subject to cost sharing. Moreover, the recently (February 2004) adopted Indonesian Water Law distinguishes between non-commercial or basic usage rights and commercial exploitation rights1; and places special consideration on 'traditional communities'.

Indonesia is currently engaged in two major reform programs with profound implications for water use, allocation and management practices. The first is the broad program of decentralisation or regional autonomy, which was enacted following the demise of Suharto's administration in 1998. The main thrust of decentralisation was implemented in 2001, which is often referred to as the Big Bang. Over 2 million civil servants were transferred from central to regional governments, along with a substantial number of service facilities and administrative functions, and regional expenditures expanded from 17% to over 30% of total government expenditures by 2001/2002 (World Bank, 2003).

The second major reform is more specific to the water resources sector. Following the Asian economic and financial crisis, international financial institutions disbursed funds contingent upon a wide range of institutional reforms. These include the $ 300 million Water Resources Sectoral Adjustment Loan, now known as WATSAP, approved in 1999. The WATSAP program has four broad objectives: (i) emphasizing coordinated water policy; (ii) integrated river basin management; (iii) water quality management; and (iv) user-managed, sustainable irrigation development. Primary principles of the WATSAP reforms include: (i) enhanced role of the local and regional level in resources and implementation authority; (ii) public-private partnerships the regional and local levels; and (iii) a participatory irrigation management system with responsibility of irrigation management in the hands of water user groups (World Bank, 1999).

One expected WATSAP outcome is a national framework for an enforceable water use rights system for both surface and groundwater and a framework for water abstraction licensing by provincial governments. Industrial and municipal abstractions are already regulated by license and subject to associated bulk water tariffs in some catchments (including the Brantas), but irrigation abstractions, in general, are not. This would appear to confer an unambiguous advantage on irrigated agriculture, the dominant user of Indonesian water resources by far, but the absence of licensing arrangements (and thus susceptibility to tariff) in fact also translates into a low de facto allocation priority and poor service to irrigated agriculture during periods of water shortage, when permit-holders are preferentially supplied. The introduction of water use rights applicable to irrigation water users holds the potential to alter this dynamic, but in ways that are as yet uncertain. The statutory endorsement of irrigators' water use rights in the new Water Law appears limited to small-scale or subsistence irrigators, defined as those withdrawing less than 2 litres per second per family. Such small-scale irrigators do not require abstraction licenses, and thus appear exempt from the bulk water tariffs accompanying commercial licenses. The implications for associations of irrigators, like WUAs or HIPPAs, are unclear, however. Moreover, the

[1] The elucidation of the Water Law spells out 2.0 l/sec as the usage threshold that distinguishes small-scale from commercial abstraction. In East Java, this would correspond to between 0.5 and 1.0 ha of irrigated paddy, approximately, but mean holdings are below 0.5 ha.

new Water Law as finally enacted made no provision for water transfers, although the DGWRD (Director General of Water Resources Development, KIMPRASWIL), has hinted that rights-based redistribution might occur so long as the government of Indonesia were involved in the process (Rodgers, personal communication, February 2004).

Another expected outcome of the water sector reforms includes a national framework for the establishment by district governments of autonomous and self-financing WUAs and WUA federations (WUAFs) to manage irrigation networks as well as a nation-wide framework for Irrigation Service Fees (ISF) to finance O&M and asset amortisation of irrigation schemes by the local government, WUAs and WUAFs. Thus, WUAs would assume many functions, which are currently the responsibility of the Water Resources Service Office under KIMPRASWIL. The ISF envisioned in this context is conceptually distinct from a bulk water tariff. It would be collected locally, by or under the authority of the WUA, calibrated to the desired or required level of anticipated O&M expenditure. Neither the Water Resources Service nor river basin authorities would, in principle, have direct access to funds generated by the ISF, although it also seems apparent that the collection of ISF to cover local recurrent costs would not eliminate the fundamental rationale for bulk water tariffs, which is the recovery of costs of maintaining dams, barrages and hydraulic infrastructure external to irrigation systems, but nonetheless required to facilitate reliable water delivery.

Water Allocation in the Brantas Basin

The model for water resource allocation studied here is the one in use in the Brantas Basin on East Java (see Figure 2), since it is often held up as a potential model for other important basins. The management responsibility for water in the Brantas River and important tributaries has been vested in one institution (Brantas Water Authority, Perum Jasa Tirta I), a public corporation that is in principle self-funding with respect to recurrent costs, but which continues to rely on the central (and foreign) governments for capital expenditures.

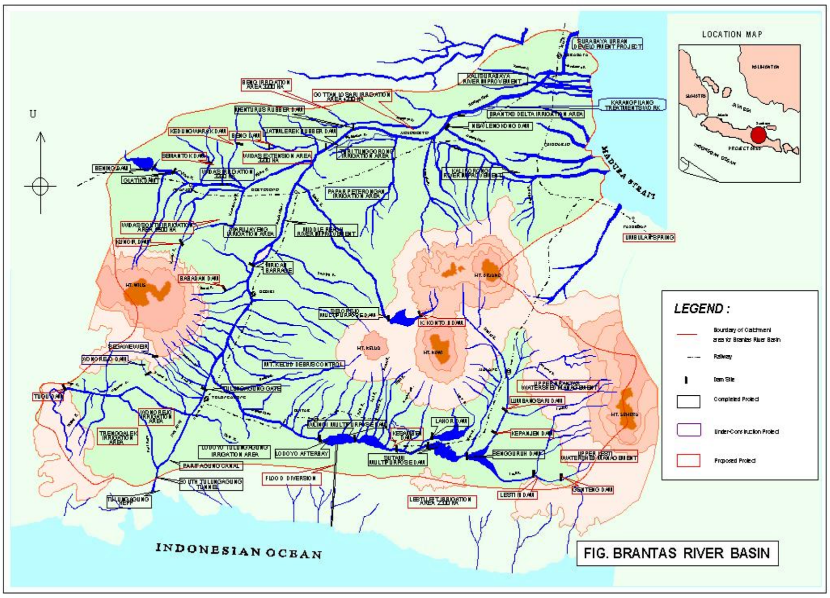

Figure 2 Location of the Brantas Basin in East Java (Indonesia)

Perum Jasa Tirta I (PJT I) is responsible for estimating available supplies and the volume and quality of water demand by the agricultural and non-agricultural sectors (domestic, industrial, power generation, social facilities, flushing, etc.), and then allocating the water among users or sectors. PJT I performs this duty, from planning through implementation, in coordination with other institutions. These include the Office of Water Resources Services, the Office of Agricultural Services, the Office for Regional Water Resource Management, and related institutions at the ministerial level. PJT I determines bulk water tariffs based on the amount needed for operation and maintenance and the quantity of water supplied. As no bulk water tariff can be charged to irrigation supplies, a cross-subsidy is determined and allocated to municipal and, in particular, industrial tariffs accordingly.

Given the importance of irrigation in overall water management, the government has established the Irrigation Committee as a cross-sectoral coordination mechanism for irrigation water management. The Committee is a coordination forum among water-related organisations and headed by the Governor at the provincial level and the district head (bupati) at the district level or mayor at the city level.

The Committee typically holds a coordination meeting before each planting period. It receives information from various higher-level institutions on current government priorities, e.g., programs for increasing food production, predictions on climate, and projections of water supply. The Committee also obtains information from local organisations on farmers' proposed cropping patterns. Utilizing these two sources of information, the Committee establishes a plan for irrigation water supply for each cropping season, which includes both volume and timing of water supply to tertiary blocks located in areas under its responsibility. Since the demand for and supply of water cannot be predicted with perfect accuracy, planting in the dry season is classified as either authorised or unauthorised. [1]

The Irrigation Committees thus use a supply management approach, with the planning of water distribution across time and location based on farmers' demand for water. It is, however, more accurate to conceptualise the pattern of water distribution as a quota system. A true supply management approach (irrigation on demand) is hard to implement for two reasons. First, it is almost impossible to obtain accurate estimates of real water demand in all locations and all periods due to the large number of farmers and the variation in cropping patterns. Second, in areas with terrace irrigation, water within a tertiary block flows naturally from one field to another on the basis of topographic gradient, without canals, making accurate measurement difficult. The modified cropping/water allocation plan as developed by the Irrigation Committee is ultimately forwarded to the Provincial Water Resources Committee (PTPA). Similar plans are submitted by municipal and industrial users, many of whom hold long-term permits or licenses. Based on these plans PJT I prepares an initial pattern of allocation for 10-day intervals taking projected supply conditions in the basin into account. The final plan is submitted to the Basin Water Resources Committee (PPTPA), which evaluates it and sends it to the Provincial Water Resources Committee (PTPA) for legal endorsement. PJT I is then responsible for implementing the plan.

[1] Authorized planting refers to dry season crops that, based on the calculation of the Committee, are likely to receive sufficient water and are therefore included in the cropping pattern plan. Unauthorized planting refers to plantings for which water supply cannot be assured, and therefore are not included in the plan. Paddy planted in the second dry season (July-September) typically falls within this category. Farmers planting unauthorized crops normally have no right to ask for additional supply if water in the field is insufficient.

The provision and monitoring of agreed-upon irrigation water supply is the responsibility of the Water Resources Service Office. Local irrigation workers, assisted by local gate tenders, are responsible for direct supply of water to the field. In general, one irrigation worker covers 5 to 10 tertiary blocks, depending on the area of the blocks and the configuration of the network. Within tertiary blocks, the farmers themselves manage irrigation collectively. The smallest level of organisation is the farmer group. To perform effectively in technical and economic terms, farmer groups join together, either voluntarily or via government encouragement, to form a WUA at the tertiary block level. Although the performance of higher-level institutions (WUAF, provincial irrigation office) in large-scale irrigation systems also affects overall irrigation management, WUAs are the institutions that directly engage farmers in everyday irrigation.

3. Price, costs and value of water ($ 1=8,500 Rp)

3.1 Price paid for canal water

Irrigating farmers in the Brantas currently pay no volumetric tariff for water. The basin water allocation agency, PJT I, recovers recurring costs via higher tariffs to municipal water supply companies and industrial users. This policy has a double edge, since when water is scarce, farmers are the first to see supplies curtailed.

Brantas farmers are subject to an irrigation service fee (ISF), payable to the local WUAs, called HIPPA. The ISF program was intended to generate operating funds for system maintenance and rehabilitation. Irrigated land (sawah) is subject to a flat, area-based fee (ISF) calibrated to reflect (i) desired level of O&M, (ii) land productivity and (iii) the ability of farmers to pay. In practice, the target ISF fell in the range of $ 1.4–1.6 (Rp 12,000–14,000)[1] per hectare per season for wetland crops, mostly rice, and a lesser amount for dry-footed crops. From its introduction in the early 1990's through the mid-1990's both ISF area coverage and collection efficiency improved, reaching a maximum in 1994/95 (with a collection efficiency of 53.5%). Following the Asian Financial Crisis (1997/98), collections were effectively suspended in the Brantas. Recognizing that ISF are predicated on local O&M and not on costs of water provision per se, the equivalent volumetric price of water would be $ 0.00025/m^3 during the wet season and $ 0.00012/m^3 during the dry season, based on mean irrigation demand at the field level of 6,000 m^3/ha during the wet and 12,000 m^3/ha during the dry season.

The ISF collection - or lack thereof - do not convey the full extent to which Brantas farmers currently pay for water service, however. Other 'hidden' payments include HIPPA administrative fees, which include officers' salaries and contingency funds; payments for pumping, including both private well and pumpset investment costs and purchases of privately pumped water; and other informal fees. The latter are extra-legal payments to various local officials in order to secure favourable treatment in the distribution of irrigation water, particularly when water is scarce. Formal ISF themselves represent only around 15% of actual water-related charges, HIPPA fees are 46%, cost of pumping 38%, and in-

[1] Ratio of CPI 2000/CPI 1997 is roughly 2.0; 2000 nominal exchange rate is Rp. 8500/$1, approximately.

formal fees 2%. Total sample-average payments for irrigation are $ 4.5/ha in the wet season (November–February), $ 5.8/ha in the dry I season (March – June) and $ 13.3/ha in the dry II season (July–October), see Table 1. This range of informal and hidden charges is seldom examined, but it is critically important in the design of water tariffs. Irrigation costs account for 1.4% of total production costs during the wet season, 1.7% during the dry I and 3.7% during the dry II season.

Table 1 Formal and Informal Water Charges, Brantas Basin

	Wet season		Dry I season		Dry II season	
	1000's Rp/ha	%	1000's Rp/ha	%	1000's Rp/ha	%
ISF fee a)	11.7	0.42	12.6	0.44	5	0.16
HIPPA fee	22.3	0.81	24.1	0.84	46	1.52
Payments for pumping	3.4	0.12	11.7	0.41	60.5	2.00
Informal fee	1.0	0.04	0.9	0.03	1.4	0.04
Total payments for irrigation	38.3	1.39	49.3	1.72	112.8	3.73
Total (cash) cost of production	2756.6	100.00	2860.7	100.00	3025.4	100.00

Source: Sumaryanto, et al. (2002)

a) Data ca. 1997; since 1998 temporarily not collected by HIPPA.

3.2 Costs of water delivery

A lower-bound estimate of the cost of irrigation water can be derived from an analysis of accumulated investment in water resources infrastructure in the Brantas Basin, based on data assembled by JICA (1998) in preparing the fourth Master Plan for the Basin.

To estimate water delivery costs (shown in Table 2), first, investment costs for all currently existing water storage and control infrastructure are resolved to a common metric, and summed. An adjustment is made to reflect the differing times of project completion and the opportunity cost of capital. Investments include dams, weirs, intakes and river improvement works. The latter are primarily investments in flood control. Investment costs in 1997 were Rp 1,299,857 million and total O&M cost Rp 11,439 million. Investment costs of irrigation works below the primary off-takes are not included, in part because project records were not readily available to Brantas authorities, and in part because many of these investments date from the Dutch colonial period. As a consequence, investments underlying the provision of irrigation service are understated, and subsequent cost estimates must be viewed as lower bounds.

Investment costs are then allocated between categories of beneficiaries, including hydropower generation, irrigated agriculture, municipal water supply, industrial water supply, flood control and river maintenance. This was done on the basis of estimated benefits accruing to each sector. Irrigated agriculture's share of benefits from accumulated investment was estimated as 68.3%, which is below its share of gross volumetric abstractions.

In a third step, investment shares and annual O&M charges are annualised and divided by the volume of water abstracted by each sector. Standardised costs for the four sectors to which benefits can be directly imputed are summarised in Table 2. The cost of water to irrigated agriculture, equivalent to the full capital and O&M recovery cost, is roughly Rp 25/m^3 in constant 1997 currency units. This is equivalent to approximately Rp

50/m^3 in constant 2000 units, or around \$ 0.006/m^3. O&M costs are \$ 0.001/m^3 in constant 2000 units. If accumulated investments in irrigation distribution and drainage networks were included, the cost would be higher, but would likely not exceed \$ 0.02/m^3.

Table 2 Derivation of Water Costs by Sector

	Investment Share	Annualised Cost a)	Annual O&M	Annual Total	Water Use b)	Full Costs c)
Sector	Rp 1997 millions				Million m^3	Rp/m^3
Hydropower	180,844	7,034.8	1,591.5	8,626.3	753,809	11.4
Irrigation Water	887,841	34,537.0	7,813.2	42,350.2	1,738	24.4
Domestic Water	21,236	826.1	186.9	1,013.0	108	9.4
Industrial Water	65,075	2,531.4	572.7	3,104.1	104	29.8

a) assuming 50 year project lifetime; 3% discount rate, CRF = 0.0389; b) units Million m^3, except hydropower, in GWH; c) units Rp per cubic meter, except hydropower, in Rp per KWH.

3.3 Value of water

The mean gross and net values of water, respectively, in irrigated agriculture can be estimated on the basis of data collected by the IFPRI/CASER 2000 sample survey of 480 farm households within four major Brantas irrigation systems (Sumaryanto et al., 2002). These systems were selected to reflect conditions in the upper-, middle- and lower- Brantas Basin. Within each system, 2 to 4 tertiary blocks were selected as representative with respect to crop allocation and rotation patterns on the basis of available cropping records, and 40 households were selected within each of the 12 tertiary blocks. Input use and output data was collected for each plot. Socio-economic data was collected for each household.

The mean value of water is calculated for four primary irrigated crops by dividing net returns per hectare by estimated field-level water demand. The latter cannot be measured directly, but rather were estimated using locally collected precipitation and canal discharges and a one-dimensional field water balance model (Rodgers and Zaafrano, 2003). Two measures of water value are estimated: gross value, including effective precipitation, and net value, relating to supplemental irrigation only. In the case of paddy, water supply includes water used for soil saturation, water layer development and losses to field percolation. Demand estimates exclude conveyance and distribution losses, and system-wide losses. Estimated values are summarised in Table 3.

Gross water requirements for paddy at field level are 11,000 - 12,000 m^3/ha assuming a fairly high level of field application efficiency (90%), roughly three times the requirements for irrigated dry-footed crops. The gross and net value of water is lower for paddy than for maize, soybeans and groundnuts. Irrigation water has a value of \$ 0.02-0.05/m^3 for paddy, \$ 0.08-0.11/m^3 for maize, \$ 0.04-0.05/m^3 for soybeans and \$ 0.04-0.08/ groundnuts. These are observed to be higher than the estimated full cost of irrigation water of \$ 0.006/m^3. One clear implication of this disparity is that volumetric tariffs set at or near cost-recovery levels are unlikely to alter levels of consumption dramatically, as values substantially exceed costs.

Table 3 Average Value of Irrigation Water, Brantas Basin 1999/2000

Crop	Season	Total Revenue	Total Cost	Profit	Gross Water	Gross Value	Net Water	Net Value
		1000 Rp/ha			m^3/ha	Rp/m^3	m^3/ha	Rp/m^3
Paddy	Wet	5,415.1	2,756.6	2,658.5	11,650	228	5,794	459
Paddy	Dry I	5,483.3	2,860.7	2,622.6	11,301	232	10,938	240
Paddy	Dry II	5,241.6	3,025.4	2,216.2	12,095	183	11,252	197
Maize	Dry I	4,832.0	2,395.1	2,436.9	3,256	749	2,565	950
Maize	Dry II	4,651.8	2,243.4	2,408.4	3,849	626	3,392	710
Soybeans	Dry I	2,439.1	1,231.3	1,207.8	3,495	346	2,653	455
Soybeans	Dry II	2,518.0	1,279.9	1,238.1	4,151	298	3,816	324
Groundnuts	Dry I	3,062.5	1,831.3	1,231.2	3,919	314	3,223	382
Groundnuts	Dry II	4,523.3	2,178.8	2,344.5	4,529	518	3,509	668

Source: IFPRI/CASER Farm Sample Survey (2000) and model simulation.

3.4 Discussion of price, costs and value of water

When faced with increased water tariffs, Brantas irrigators have the following options: (i) they can change the cropping pattern, growing less paddy and more low-consumption crops; (ii) they can alter the timing of planting, to more effectively exploit rainy season precipitation; (iii) they can apply less irrigation water, effectively moving down the water-yield curve (but keeping in mind lower-lying fields that depend on upper-terrace flows); (iv) they can substitute other factors (like labour, fertiliser) for water, to a point; and (v) they can switch to rainfed cultivation, or fallow land. In the medium term, farmers can select cultivars that are more drought- or salt-tolerant, or that mature in shorter periods. They can also elect to invest in private pumpsets, or in irrigation technologies that increase the precision of water delivery, thereby increasing field application efficiency. In the Brantas, however, the dominant cropping practice is wet-transplant paddy, and no technical alternatives to flood irrigation in paddy cultivation have been proven for large-scale application in this region.

Data for the Brantas Basin in East Java suggest that the average value of water of \$ 0.04/m^3 in the production of important irrigated agricultural crops substantially exceeds the estimated costs of provision of \$ 0.006/m^3. In this case, the introduction of volumetric tariffs that recover costs would not necessarily lead to substantial water savings, although they would clearly have adverse effects on farm sector income. Results of simulation modelling in the Brantas[1] (Rodgers, 2004) suggest that charging farmers a volumetric tariff approximating full cost recovery levels would indeed impose a substantial burden on farm economic welfare, while resulting water savings would be relatively modest. Very little real savings in gross and net irrigation water withdrawals occurs at low volumetric prices (\$ 0.001-0.004/m^3 at the tertiary block level), but such savings become significant at around \$ 0.005/m^3, exceeding 20 million m^3 (net) at \$ 0.006/m^3. This is roughly 1% of gross irrigation abstractions under historical and baseline conditions, which may appear in-

[1] The analysis was carried out with a basin-scale, integrated economic-hydrologic-agronomic simulation-optimisation model of the Brantas basin developed by Rodgers and Zaafrano (2003).

consequential but would in fact provide a substantial additional buffer to municipal and industrial water demand, and would also provide additional flows for environmental purposes. Unfortunately, tariffs in excess of \$ 0.005/m^3 would likely impose serious economic hardship on farmers, as they represent substantial increases in costs. The latter assertion is supported by evidence that farmers already incur substantial informal costs to secure reliable water supply, which would not necessarily be reduced or eliminated in the event that volumetric tariffs were introduced.

4 Recommended policy instruments

While volumetric irrigation fees would help recover costs, they would be difficult to implement at the farm level and conserve little water up to a very high level, while adversely impacting farmer incomes. Alternative instruments to save water in irrigated agriculture, particularly paddy cultivation, are being discussed in the following.

Enhanced irrigation efficiency
Volumetric costs and other incentives only succeed in inducing significant changes in levels and patterns of irrigation water use, if inefficiencies in water allocation exist that can be eliminated. Three types of inefficiency are discussed: physical inefficiency, operational (or managerial) inefficiency, and allocative (or economic) inefficiency. The potential for real water savings was analysed based on the Brantas simulation model. Agricultural land area in the basin cannot be expanded; additional irrigation would be possible in the dry season, however.

Physical efficiency is defined as the ratio of water used beneficially to water withdrawn for that purpose, here at the irrigation system scale. It is a statement about the quality of design and construction and the existing condition of the infrastructure itself, and by implication, the accumulated investment in the maintenance of that infrastructure. SRPCAPS (1999) estimated overall Brantas Delta irrigation efficiency at 27%, with an intake efficiency of 61%, a system operation efficiency of 56%, and a tertiary and on-farm efficiency of 79%. These estimates embody both physical and operational sources of inefficiency.

Operational efficiency refers to the effectiveness by which system managers are able to match the spatial and temporal pattern of demand with effective supply. It encompasses their knowledge of these patterns of demand, of the hydraulic behaviour of the system, and the flexibility with which they respond to transient circumstances such as meteorological events. An estimate of water savings from removing operational inefficiency can be obtained through optimising the pattern of gross abstractions based on observed historical patterns of planted area. Under this comparison, gross abstractions to Brantas irrigation systems can be reduced by 640 million m^3 per year. Assuming that roughly 30% is returned as drainage, net savings of roughly 450 million m^3 per year can be obtained. These are, however, not fully realizable savings, due to remaining uncertainty of basin operators regarding cropping pattern and climate data, among others, and due to the impossibility to achieve near-perfect operational efficiency within irrigation systems. However, even if current losses to operational inefficiency could be reduced by around 45%, it might be possible to divert roughly 200 million m^3 per year from irrigated agriculture to other uses.

Finally, economic (alternatively Pareto) efficiency is a statement about the effectiveness of water allocation across categories and locations of use, each having unique average and marginal unit value products. An economically efficient allocation is one in which it is not possible to improve aggregate 'welfare' by transferring a unit of water from one location or use to another. Based on the Rodgers and Zaafrano (2003) model, an estimate of the extent of overall allocative inefficiency on the Brantas Basin can be obtained by comparing the historical pattern of water allocation with an optimised baseline pattern of allocation, where the model incorporates municipal and industrial uses, hydropower generation, and environmental flows in addition to irrigated agriculture. Under the baseline economic optimisation scenario, irrigation abstraction falls from 88.7% of total offtakes to 81.4%, while municipal withdrawals increase from 7.6% to 13.8% and industrial withdrawals from 3.7% to 4.8% of total offtakes, respectively.

To summarise the efficiency estimates, (i) the technical (physical) efficiencies of Brantas surface irrigation systems are below realizable potential levels, but not unusual for Asian surface irrigation standards; (ii) there is a substantial degree of operational inefficiency in bulk irrigation deliveries, as evaluated at system offtake points, representing a significant opportunity to increase effective Basin supplies through improvement in operational protocols, including interagency cooperation; (iii) there is a modest degree of intersectoral allocative inefficiency, specifically a relative under-supply of municipal water supply companies and, to a lesser extent, industrial demand and corresponding over-supply to irrigated agriculture. These results indicate that the primary sources of inefficiency are beyond the influence of individual farmers, or WUAs. Moreover, on-farm efficiency improvements, like field level irrigation technology improvements and alternative cropping schedules, does not work well in the Brantas, particularly in areas with steeper topography, depending on field-to-field water flows. In that case, the introduction of tariffs is likely not only to fail in achieving management objectives, but may have substantial negative impacts on farm incomes and rural welfare.

Enhanced crop water management of paddy

Studies on the trade-off between water and yield for paddy have been carried out for some time. According to Bouman and Tuong (2001) who synthesise the results of 31 studies, field-level water productivity can be improved substantially, with the most significant marginal increases obtained at relatively high levels of application, i.e., modest reductions relative to conventional (full) water input levels are achieved with very little loss of yield. For techniques that reduce ponded depths while keeping soil near saturation, water savings averaged 23% while corresponding yield reductions averaged only 6%.

A more recent but growing body of research indicates that it may be possible to expand rice yields while simultaneously reducing water requirements under high levels of management and technical control. In the System of Rice Intensification (SRI), for example, the soil is kept well drained through the vegetative period, and shallow flooding is only introduced upon panicle initiation. The SRI also involves transplanting of young (8-12 day) seedlings and wide spacing of transplants (Uphoff and Fernandes, 2002). Integrated Crop and Resource Management (ICM) as practiced in research facilities in

Indonesia involves many of the same strategies as SR - young transplants, wide spacing and alternating periods of submergence and drainage - and in addition the management of soil organic material and monitoring of soil nutrient status via colour charts (Gani et al., 2003). The impact of new water-saving rice cultivation techniques is summarised in Table 4. The trade-offs between yield and water vary across studies, but typically a reduction in water supply does lead to lower yield. Moreover, all of these systems are highly knowledge-intensive, and an extensive farmer learning curve is likely involved. The feasibility of practicing such management-intensive cultivation techniques on wider scales will depend critically on the redesign of surface irrigation systems and management protocols to permit greater precision and coordination in water control.

Table 4 Yield and Water Use Impacts of New Water-Saving Rice Cultivation Techniques

				% Change in:b)		
Study	Year	Location	Method a)	Yield	Water	Comments
Gani, et al.	2003	W Java	INT	3.7	-54.0	
Gani, et al.	2002	Sumatera	SRI	41.2	-	Dry matter as yield proxy
Wardhana, et al.	2002	Indonesia	ICM	16.0	-	Four Provinces
Makarim, et al.	2002	S Sulawesi	SRI	-0.2	-	
Gani, et al.	2002	Indonesia	SRI	13.5	-	Seven Provinces
Uphoff, et al.	2002	15 Countries	SRI	68.3	-	Compare SRI to national average
Shi, et al.	2002	China	INT	2.8	-27.4	Excludes precipitation
Belder, et al.	2002	China	ASNS	-1.9	-9.7	
Thiyagarajan, et al.	2002	India	SRI	-1.4	-40.3	Tamil Nadu
Dong, et al.	2001	China	AWD	7.2	-12.6	Gross water productivity
Hauqi, et al.	2002	China	AER	-30.9	-60.4	Guanshuang, Beijing
Xiaoguang, et al.	2002	China	AER	-46.4	-59.9	
Castaneda, et al.	2002	Philippines	AER	-24.6	-44.8	IRRI
Lin, et al.	2002	China	GCRPS	-18.6	-51.1	

a) Cultivation methods: INT Intermittent Irrigation, SRI System of Rice Intensification, ICM Integrated Crop and Resource Management, ASNS Alternate Submerged - Non submerged, AWD Alternate Wet-Dry, AER Aerobic Rice and GCRPS Ground Cover Rice Production System.
b) Change measured relative to conventional flooded rice cultivation.

Aerobic rice cultivation currently appears less promising with regard to yield, but results show substantially reduced water inputs, often by more than half, so that the productivity of water is still higher than under conventional flooded cultivation systems. As genetic selection is an important component of the aerobic rice approach, yields will likely improve as research progresses at the International Rice Research Institute (IRRI) and elsewhere. Other approaches, including the Ground Cover Rice Production System (GCRPS), reduce water use directly by covering the soil with plastic film after irrigation and can produce potential water savings of the same order, although environmental externalities may present new challenges.

Water Brokerage Mechanism

As an alternative economic instrument to water tariffs, Rodgers and Zaafrano (2003) analysed a water brokerage mechanism that would be governed by PJT I responsible for bulk water deliveries in the Brantas Basin. The analysis was again carried out with the basin-scale, integrated economic-hydrologic-agronomic simulation-optimisation model developed for the Brantas basin. In the Water Right with Brokerage (WRBRK) simulation for the Brantas basin, each major water user, including municipal water supply companies, industries, and WUAs at the tertiary block level, has water use rights that are specified at the off-take level based on historic water uses, but with removal of apparent 'excessive' inefficiencies. For irrigation, the tertiary block is the lowest level of irrigation system management at which point water deliveries can be measured accurately. In addition, water users are now able to purchase additional water from PJT I at a fixed, flat rate of Rp 35/m^3 subject to system-wide water supply constraints and competition from other demand sites; and they are also free to sell a portion of their own entitlement back to PJT I at the same price.1 Sales are implemented on a monthly basis. The WRBRK system is compared with a system, where water users in all sectors (again WUAs for irrigation) obtain fixed permits or quotas, without the possibility of buying additional or selling unused permits, and a system, where no permits are handed out to the irrigation sector, but water is being priced closer to its providing costs. All results are compared to a base case, where no rules or regulations for water allocation are specified (Table 5). Under the volumetric water tariff, net irrigation abstractions decline by 10 million m^3, but farmer incomes drop by Rp 45 billion in the Brantas irrigated agricultural sector. Under a quota system, where farmers have a fixed, but small allocation of water, considerable amounts of water can be saved in irrigation (290 million m^3), but net costs to farmers are even higher, at Rp 60 billion. Under the WRBRK system, finally, the same water use rights are maintained, but farmers (and other users) have the possibility to purchase additional temporary permits at the flat rate used in the volumetric tariff from PJT I, or sell water to PJT I at the same flat rate, making a profit in the process. In this particular scenario, the brokerage mechanism leads to annual net water savings of 37 million m^3 compared to the baseline, most of it in the wet season, while farm income declines by only Rp 2.5 billion compared to the base case.

Table 5 Changes in Irrigation Abstractions and Farm Incomes, Alternative Allocation Mechanisms

Scenario	Decrease in Net Irrigation Abstractions		Reduction in Net Income, per Year	
	Annual	Dry Season	Agriculture	
	Million m^3		Billion Rp	Rp/m^3
Volumetric Tariff, Rp 35/m^3	10.1	4.9	44.8	4,450
Quota allocation, based on fixed water rights	289.6	171.6	60.4	208
Water right with brokerage (WRBRK)	37.2	19.6	2.5	67

[1] In comparison, municipal water supply companies paid a bulk water tariff of Rp 40/m^3 in 2003.

Thus, while more water could be saved by the quota system, by simply denying water to farmers, the WRBRK achieves significant water savings at very little cost to the irrigated agriculture sector. Moreover, if WUAs use part of the money for investment in on-farm efficiency improvements both objectives, water savings and financial autonomy of WUAs can be achieved. Well-established water use rights, combined with an economic incentive operating at the margin (water rights with brokerage mechanism) are capable of producing allocative efficiency at nearly the same level as pure markets. In addition, efficiency is gained without penalizing the incomes of poor farmers.

In summary, the best short-term means to conserve water is to enhance allocation of water among irrigation districts in the Brantas, i.e. to increase operational efficiency. Secondly, farmers need to obtain water use rights/permits, if not themselves, then through WUAs, to establish a base for compensation as water is increasingly transferred to urban-industrial users, particularly under drought conditions. Thirdly, farmers need to have more say in cropping strategies and water allocation, and, in that process will likely agree to increase support for O&M of systems. Enhanced canal maintenace will again save water. Finally, in the medium term, enhanced crop cultivation strategies, particularly for rice, and water marketing at the tertiary block level with other sectors, will help save water while not negatively impacting farm incomes. With SRI for instance non-recoverable losses as well as the quantity of water lost to evapotranspiration can be reduced. It will take time to introduce SRI, however, as it is highly knowledge-intensive and requires more control over water allocation. The water brokerage mechanism would need to be pilot tested and large-scale application would need to follow the implementation of a new water rights framework based on the new Water Law, which might well take several years.

Complementary strategies are selected new infrastructure developments (one or two more dams) and the already ongoing crop diversification (for example, more maize and less rice) while rice production slowly shifts out of Java (but keeping in mind that rice self-sufficiency remains an important government objective and that rice productivity off-Java is far below yields achieved on Java).

5. Conclusions

Indonesia possesses soils and climate that are advantageous for irrigated agricultural production, although population pressure and economic development, particularly on densely populated Java, have resulted in increasing competition for available water resources. Paddy productivity is high by world standards, particularly on Java, although yields have stagnated in the mid- to late 1990's. Moreover, while returns to irrigation investment have been high in the past, cost recovery of these investments has been low, hampering new, more expensive developments, as the most suitable locations have been exhausted. Lack of O&M recovery also stands in the way of irrigators taking on management functions of irrigation systems under the current decentralisation and water sector reform efforts.

The government of Indonesia holds clear authority over the management of water resources, and has the statutory right to charge beneficiaries for the provision of services related to the management and provision of water resources. Current water sector reforms are intended to strengthen the capacity of local institutions to co-manage water resources.

Important aspects of these reforms include the implementation of formal water use rights, the emphasis on integrated water resources management at the river basin level, the strengthening of water users' associations and the improved viability of local water management institutions via enhanced cost recovery. However, the new Water Law exempts small-scale irrigators from obtaining permits as a manifestation of their water use right.

Data from the Brantas Basin in East Java suggest that the average value of water in the production of important irrigated crops substantially exceeds estimated water supply costs, defined as full capital and recurrent cost recovery. Irrigation service fee collections in the Brantas are low, particularly since the Asian Financial Crisis of 1997/98. However, farmers pay a series of local and informal water charges that are still low, but substantially exceed formal ISF.

Charging farmers a volumetric tariff approximating full cost recovery levels would, however, impose a substantial burden on farm economic welfare, while water savings would be relatively modest. The design of the irrigation delivery system and the small size of plots limit the possibility to use volumetric water pricing at the plot level.

All three types of efficiencies discussed, physical, operational, and economic efficiencies have potential for improvement in the Brantas. However, as a result of the relative profitability and limited water-saving technologies for paddy, the existence of terrace irrigation systems in some areas of the basin, where irrigation water flows across fields through terraces and not canals, and the lack of control over water supply reliability at the tertiary block level, farmers have limited actual room for conserving water. If primary sources of inefficiency are beyond the influence of individual farmers, or water users' associations, then the introduction of volumetric water use tariffs will not only fail to achieve its objective, but may also have substantial negative impacts on farm incomes.

Research on water-saving techniques for paddy cultivation indicate that it is difficult to maintain yields if water inputs are substantially reduced; although some highly intensive management methods, like the intermittent irrigation application researched by Gani et al. (2003) can both produce significantly increased yields while saving substantial quantities of water. The feasibility of practicing such management-intensive cultivation techniques on wider scales will depend critically on the redesign of surface irrigation systems and management protocols to permit greater precision and coordination of water control.

A water allocation approach combining water rights with a water brokerage mechanism achieves efficient outcomes and appears to be politically and administratively feasible in the Brantas basin. A fixed base rate would be charged to cover an appropriate portion of O&M costs and depreciation. The base right would reflect close to historical allocation levels, and user groups would be responsible for internal water allocation. The WUA or WUA federation and other users would then be charged (or paid) an efficiency price equal to the value of the water in alternative uses for demand above (or below) the base. This approach requires further development, including pilot testing to overcome the politically difficult, but feasible challenge of establishing base water rights, base charges, and efficiency price. The cornerstone of this approach, and any other means for improving water use efficiency in irrigation while preserving the economic welfare of the irrigated agricultural sector- is the strengthening of irrigators' water use rights, so that farmers can benefit directly from any improvements in irrigation water use efficiency that are passed on to other sectors.

References

Belder, P., B. A. M. Bouman, J. H. J. Spiertz, Lu Guoan and E. J. P. Quilang, 'Water Use of Alternatively Submerged and Nonsubmerged Irrigated Lowland Rice'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production*. Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Banos, Philippines. IRRI. 2002.

Bouman, B. A. M., and T. P. Tuong, 'Field Water Management to Save Water and Increase its Productivity in Irrigated Lowland Rice'. In: Agricultural Water Management 49 (2001), pp. 11-30.

Castaneda, A. R., B. A. M. Bouman, S. Peng and R. M. Visperas, 'The Potential of Aerobic Rice to Reduce Water Use in Water-Scarce Irrigated Lowlands in the Tropics'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Banos, Philippines. Los Banos: IRRI. 2002.

Dong, B., R. Loeve, Y. H. Li, C. D. Chen, L. Deng and D. Molden, 'Water Productivity in the Zhange Irrigation System: Issues of Scale'. Chapter 6 in: Barker, R., Y. H. Li and T. P Tuong (Eds.), *Water-Saving Irrigation for Rice*. Proceedings of an International Workshop held in Wuhan, China, 23-25 March 2001. Colombo, Sri Lanka: IWMI. 2001.

Gani, A., A. Rahman, Dahono, Rustam, H. Hengsdijk, 'Synopsis of Water Management Experiments in Indonesia'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.) *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production, 8-11 April 2002, Los Banos, Philippines. IRRI. 2002.

Gani, A, I. Juliardi, D. Setiobudi , H. Hengsdijk, P. Henstra and P.S. Bindraban, *Effect of Water Management, Organic Matter and Phosphate Fertiliser on Rice*. Paper presented at International Symposium on Transition in Agriculture for Enhancing Water Productivity from 23 to 25 September 2003 at Agricultural College and Research Institute (ACRI), Killikulam-Tamil Nadu, India. 2003.

Hauqi, Wang, B. A. M. Bouman, Dule Zhao, Wang Changgui and P. F. Moya, 'Aerobic Rice in Northern China: Opportunities and Challenges'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production. IRRI, Los Banos, Philippines. 8-11 April 2002.

Japan International Cooperation Agency (JICA); Nippon Koei Co. LTD and Nikken Consultants, *The Study on Comprehensive Management Plan for the Water Resources of the Brantas River Basin in the Republic of Indonesia.* (Master Plan IV) 5 volumes. 1998.

Lin, Shan, K. Dittert, Hongbin Tao, C. Kreye, Yangchu Xu, Qirong Shen, Xiaolin Fan and B. Sattelmacher, 'The Ground-Cover Rice Production System (GCRPS): A Successful New Approach to Save Water and Increase Nitrogen Fertiliser Efficiency?' In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha(Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production. IRRI, Los Banos, Philippines. 8-11 April 2002.

Makarim, A. K., V. Balasubramanian, Z. Zaini, I. Syamsiah, I. G. P. A. Diratmadja, Handoko, Arafah, I. P. Wardana and A. Gani, 'System of Rice Intensification (SRI): Evaluation of Seedling Age and Selected Components in Indonesia'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production, IRRI, , Los Banos, Philippines. 8-11 April 2002.

Rodgers, C, *The Role of Economic Incentives in Promoting Improved Water Use Efficiency in Indonesian Irrigated Agriculture*. IFPRI, Paper prepared for LEI. 2004.

Rodgers, Charles A. and Rizaldi Zaafrano, *A Water Resources Management Policy Simulation Model of the Brantas Basin, East Java, Indonesia.* Invited paper prepared for the Panel on Water Policy and Agricultural Production at the Global and River Basin Levels. IAAE Meetings, Durban, South Africa, August 16-23, 2003.

Rosegrant, M. W., F. Kasryano and N. D. Perez, 'Output Response to Prices and Public Investment in Agriculture: Indonesian Food Crops.' In: *Journal of Development Economics*, 55 (1998), pp. 333-352.

Rosegrant, Mark W., Ximing Cai and Sarah Cline, *World Water and Food to 2025: Dealing With Scarcity*. Washington, D.C.: International Food Policy Research Institute.2002.

Shi, Qinghua, Xiaochun Zeng, Muying Li, Xueming Tan and Fengfeng Xu, 'Effects of Different Water Management Practices on Rice Growth' . In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production*. Proceedings of the International Workshop on Water-Wise Rice Production. IRRI, Los Banos, Philippines. Los Banos. 8-11 April 2002.

SRPCAPS (Surabaya River Pollution Control Action Plan Study), *Surabaya River Pollution Control Action Plan Study.* (SRPCAPS) (Surabaya Urban Development Project, Technical Assistance from IBRD Loan No. 3726-IND). Binnie & Partners (Overseas) LTD in association with PT. Indra Karya; PT. Multi Tehniktama Prakarsa; PT. Exsa International Co. LTD. 5 volumes. 1999.

Sumaryanto, M. Siregar, and M Wahida (Center for Agro-Socioeconomic Research), *Socio-Economic Analysis of Farm Households in Irrigated Area of Brantas River Basin.* Paper prepared for the Final Policy Workshop, Irrigation Investment, Fiscal Policy and Water Resources Allocation in Indonesia and Vietnam, held in Ho Chi Minh City, 21-23 November 2002.

Thiyagarajan, T. M., V. Velu, S. Ramasamy, D. Durgadevi, K. Govindarajan, R. Priyadarshini, C. Sudhalakshmi, K. Senthilkumar, P. T. Nisha, G. Gayathry, H. Hengsdijk and P. S. Bindraban, 'Effects of SRI Practices on Hybrid Rice Performance in Tamil Nadu, India'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production. IRRI, , Los Banos, Philippines, 8-11 April 2002.

Uphoff, Norman and Erick C. M. Fernandes (Eds.), *Assessment of the System of Rice Intensification (SRI).* Proceedings of an International Conference Held in Sanya, China, April 1-4, 2002.

Wardhana, I. P., P. S. Bindraban, A. Gani, A. K. Makarim and Irsal Las, 'Biophysical and Economic Implications of Integrated Crop and Resource Management for Rice in Indonesia'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production.* Proceedings of the International Workshop on Water-Wise Rice Production. IRRI, , Los Banos, Philippines, 8-11 April 2002.

World Bank, *Indonesia at a glance.* (http://www.worldbank.org/data/ countrydata/ aag/idn_aag.pdf). 2003.

World Bank, East Asia and Pacific Region, Rural Development and Natural Resources Sector Unit, *Report and Recommendations of the President of the International Bank for Reconstruction and Development to the Executive Directors on a Proposed Water Sector Adjustment Loan in the Amount of $ 300 Million to the Republic of Indonesia*. Report No. P 7304-IND (WATSAL). 1999.

Xiaoguang, Yang, Wang Huaqi, Wang Zhimin, Zhao Junfang, Chen Bin and B. A. M. Bouman, 'Yield of Aerobic Rice (Han Dao) Under Different Water Regimes'. In: Bouman, B. A. M., H. Hengsdijk, B. Hardy, P. S. Bindraban, T. P. Tuong and J. K. Ladha (Eds.), *Water-Wise Rice Production*. Proceedings of the International Workshop on Water-Wise Rice Production, IRRI, , Los Banos, Philippines. 8-11 April 2002.

Appendix F Morocco - Tadla

Abstract
Morocco is currently already using very suitable instruments -rationing and some volumetric charging- to govern demand for canal water and to recover O&M costs. To overcome the constraints of inflexibility and the quantity of surface water availably, many farmers have invested in private tubewells, where the unit price of water is more than double that of surface water supplied. To control groundwater use, it is recommended to define entitlements for groundwater use in Tadla. The volumetric canal water fees currently charged in Tadla cover O&M costs, but are substantially less than the returns to irrigation water.

1. Introduction

In 2002 Morocco had a population of 29.6 million of which 43% live in rural areas; at least 35% of the population are farmers. Agriculture accounts for 16.1% of GDP. Average per capita income is $ 1190 (World Bank, 2003). The total size of Morocco is 71 million ha, but is has only 9 million ha of utilised agricultural area (13%). Average rainfall is less than 300 mm, but is variable in time and space (50mm in Saharan zones and 2000 mm in mountainous regions).

Morocco's climate makes rainfed agriculture uncertain and of generally low productivity, especially in southern areas where rainfall is highly variable and on average far less than potential evapotranspiration. Production from rainfed arable land consequently varies widely. About 1.6 million of the 7.7 million hectares of arable land can potentially be irrigated.

Irrigated areas account for 45% of agricultural value-added and 75% of agricultural exports (Ait Kadi, 2002). Irrigation currently accounts for 88% of water use (domestic and industrial use accounting for 8% and 4% respectively). The availability of renewable water is just 1045 m^3/person/year; projected increases in population are expected to reduce that figure to about 750 m^3/person/year by 2020 (El Yacoubi and Belghiti, 2002).

This paper will focus on the Tadla region, a vast plain 70 km long and 40 km wide. The utilised agricultural area covers 300,000 ha, including 124,000 ha of irrigated land. About 100,000 ha is served by large-scale irrigation, 20,000 ha by small-scale irrigation and 4,000 ha by drip irrigation (Papin, 2003). The adoption of drip irrigation (goutte-à-goutte) is encouraged, which enables the cultivation of new crops, such as melon. Farmers with drip irrigation do not get more water, but more flexible turns (more hours at a lower discharge).

The Tadla irrigation system consists of lined open canals, receiving water by gravity from the Bin el Ouidane and Ahmed El Hansali dams and allows for calculating delivered water volume to individual farms. It is the oldest perimeter. The perimeter is divided in two parts by the river 'Oum er Rbia': Beni Moussa at the left and Beni Amir at the right.

Beni Amir needs 420 million m^3 of water and Beni Moussa 710 million m^3. In 2003 considerably less water was, however, allocated to Beni Amir (150 million m^3) and Beni Moussa (350 million m^3). Water is also supplied by about 10,000 private wells (officially there are only 200-600 wells) - a trend that has increased over recent years in the face of regular drought. The majority of pumps are powered by diesel engines, with an average discharge of 15 l/s.

2. Water problems, policies, infrastructure and institutions

2.1 Water problems and policy objectives

Morocco receives an annual average rainfall of 150 billion m^3, although this figure is variable. Of this total, 21 billion m^3 (17 billion m^3 surface and 4 billion m^3 groundwater) is usable. In 1990 the estimated national water balance showed an availability of 11 billion m^3, with demand at 10.9 billion m^3. The supply of water is expected to rise to 16.8 billion m^3 by 2020 (as a result of dam construction and the development of additional aquifers). Demand for water is expected to be higher at 17.6 billion m^3, with irrigation accounting for 4.8 billion m^3 or 70% of the increase (Ait Kadi, 2002). Of course these figures are estimates and therefore open to question. However, they indicate that Morocco's currently developed resources are fully utilised and that future surpluses are unlikely as infrastructure development is unlikely to keep pace with demand.

An additional concern is deteriorating water quality, with increasing amounts of water needed to flush and dilute pollution loads (particularly high salinity and sediment). In Tadla, farmers increasingly compensate for the deficit of surface water by using groundwater, which is often highly saline, prompting concern over the sustainability of groundwater development. Furthermore, because the farmers use groundwater and canal water at the same time to avoid damaging the crop, the actual 'substitution' of surface water by groundwater is minimal.

In these circumstances, the main factor constraining agricultural production is availability of water. Faced with scarcity of canal water and overexploitation of groundwater, a number of policy objectives have emerged: to balance supply and demand of groundwater; to reduce overall water consumption in agriculture; to increase the productivity of water consumed, and to increase cost recovery. Environmental sustainability is another important objective, as there are waterlogging problems due to excess recharge.

2.2 Existing policy instruments

In 1993, a National Irrigation Program was launched. The Program had two main aims:

- Horizontal expansion to reduce the gap between dam and command area development
- Improving the performance of irrigated agriculture, through more efficient water use and higher crop yields, and improved managerial capacity within the ORMVAs

Under the 1993 Program, a reduction in losses and increase in water productivity were to be achieved through:

- Rehabilitation (200,000 ha planned, mostly in small/medium sector).
- Improving water delivery to farmers – better O&M, more modern management; strengthening the relationship between ORMVAs and farmers.
- Establishing WUAs - the objective is not transfer, but organising farmers to participate.
- Improved on-farm water management.

At present, the demand for water exceeds supplies. As a result, canal water is rationed in accordance with a schedule set out at the beginning of the irrigation season (September). Quotas for canal water -seasonal allocation depending on availability- are quantified by farm and measured close to the point of delivery. The limitation of water use provides and incentive for users to avoid waste and irrigate crops with a high return to water. It provides a transparent means of allocating water, ensuring that consumption of water is controlled, and making farmers individually appreciate that water is scarce. Water allocation per hectare is determined by a regional commission, based on dam reserves and projected rainfall, and can be adjusted according to actual rainfall. This means that there are defined water rights for canal water. There are also volumetric water fees for the use of canal water (discussed in more detail in Section 3.1), which serve predominantly as a means of cost recovery and only to a limited extent as an instrument of demand management.

As far as groundwater is concerned, the principle of state ownership of water has been in place since 1914. However, there are currently no defined entitlements for the use of groundwater. There are nominal restrictions on the pumping of groundwater (no deeper than 40 m below soil surface), although in practice the restriction is rarely enforced and is therefore not an effective policy instrument. In any case, the majority of farmers install wells without obtaining the required authorisation. It is also worth noting that the amount of groundwater pumped varies widely from year to year due to large variations in rainfall.

An alternative policy instrument aimed at limiting groundwater extraction is currently being drawn up. Under the new system, the River Basin Committee will be empowered to charge for water extracted, on the basis of the number of pumping hours. Given the problems with enforcement of existing regulations on installation and operation of pumps, it is not obvious that measurement of hours pumped will be easy to measure and use as an instrument of demand management.

Since 1965, more than 65% of the public investments dedicated to agriculture is allocated to irrigated agriculture (Herzenni, 2001) The objectives of this investment policy and the irrigation it has supported are to improve self sufficiency through a better coverage of the needs and products of basic food. Find an equilibrium in the 'trade balance' through the development of agricultural exports. Improve the living conditions of the rural population. Add value to agricultural products through the development of the agro-industry.

Tadla in Morocco is one of the largest irrigation schemes in the country - almost 100,000 ha of surface irrigation. Tadla is already using very suitable instruments- rationing canal water combined with volumetric charging -to recover O&M costs and discourage wasteful use. A considerable increase in the price of canal water would be needed to balance supply and demand, but seems socially undesirable as it imposes a substantial burden on farm economic welfare and might trigger an increase in (unsustainable) groundwater usage. Rationing of canal water use is therefore likely to remain the dominant instrument. Recently the government proposed to reduce irrigation charges by giving farmers a greater management role, by means of Participatory Irrigation Management. This does not seem to be successful in Tadla, as financial incentives (remissions of charges) when farmers take over tasks are limited. Tadla is, however, not a representative irrigation project. To overcome constraints of canal water availability and flexibility many farmers have invested in private tube wells, while (as in Haryana) policy to control groundwater use has not received a lot of attention.

2.3 The irrigation infrastructure

Surface irrigation development in Morocco are often classified into large, medium and small systems, which comes down to formal and informal systems. The formal systems, developed over the last forty years, are larger and government-planned and financed. There are nine modern large-scale irrigation schemes in the country, each overseen by an ORMVA (Office Régional de Mise en Valeur Agricole). The informal systems are generally smaller and older, and include community-developed systems that exploit local surface water resources through traditional groups, as well as more recent private groundwater developments (Wallingford, 2003).

The infrastructure was designed for a specific situation: the irrigation of an area characterised by an obligatory cropping pattern at the farm level, with crops organised in homogeneous blocks served by a common watercourse. The system was logical when cropping patterns were enforced so that Plot A (see Figure 1) for each farm was under the same crop and could be provided with a water-delivery schedule suited to that crop (Wallingford, 2003). Known as the Trame B model, this system simplified water scheduling and management because each watercourse was operated to serve a specific crop and its specific water requirements. However, in the 1980s cropping patterns were liberalised to enable water to be distributed on a farm rather than a crop basis – with the result that the 30-year old design no longer corresponds to the current management situation. However, the ORMVA management still issues clear 'guidance' on feasible cropping plans prior to each season, especially when water is scarce. During years of water shortage the ORMVAT comes up with the priority crops for which water allocation is guaranteed.

Under the new circumstances, it is difficult to fix irrigation schedules. However, farmers are familiar with the system and probably consolidate their turns fairly effectively. The liberalisation of the cropping pattern has led to modifications of the infrastructure used by farmers. Farmers are using mud to divert water from the tertiary canals to the fields, with the result that water is now more often conveyed in earthen canals (sequia) than in concrete canals, leading to higher water losses. In response, the ORMVA has designed a new model for distributing water that is being implemented in rehabilitations of secondary canals (Papin, 2003). The Trame B does not work satisfactory anymore.

Morocco uses French-designed systems of irrigation, entailing a high level of control up to farm level. The Moroccan systems provide water for both sprinkler and surface irrigation. In the sprinkler-irrigated areas, delivery is on a demand basis: water is pumped into pressurised pipes; farmers operate valves to release the water and are billed for the volume taken.

In the case of surface deliveries, water flows under gravity or is pumped from distribution canals or rivers into 'canaletti' - concrete channels suspended on pillars. These are of standard dimensions. They can be carrying 120 l/s before branching off into 30 l/s earthen watercourse channels from which the farmers take water. At each branching point, 'modules à masque' (stepwise or baffle distributors) are constructed, which provide accurate supplies to each off-taking channel, relatively independent of the upstream water level in the parent canal.

Channel>>					
Farm 1 Plot A	Farm 1 Plot B	Farm 1 Plot C	Farm 1 Plot D	Farm 1 Plot E	Farm 1 Plot F
Farm 2 Plot A	Farm 2 Plot B	Farm 2 Plot C	Farm 2 Plot D	Farm 2 Plot E	Farm 2 Plot F
Farm 3 Plot A	Farm 3 Plot B	Farm 3 Plot C	Farm 3 Plot D	Farm 3 Plot E	Farm 3 Plot F
Farm 4 Plot A	Farm 4 Plot B	Farm 4 Plot C	Farm 4 Plot D	Farm 4 Plot E	Farm 4 Plot F
Farm 5 Plot A	Farm 5 Plot B	Farm 5 Plot C	Farm 5 Plot D	Farm 5 Plot E	Farm 5 Plot F

Figure 1 Schematic of watercourse and farm plot layout

Field observations indicate that while individual modules can be adjusted to various flow rates (30, 60 or 90 l/s), most are fixed to a particular rate, ensuring consistent rates of delivery. Since the water demand schedule for the various crops is different, the watercourses are arranged to run at right angles to the ownership boundaries so that each watercourse can be operated to serve the needs of a specific crop (see Figure 1: the channel is the bold line at the top; watercourses are indicated by the vertical double lines). System losses are low in the case of the surface systems (where all channels except the watercourses are concrete), and minimised in the case of the sprinkler systems where delivery is through pipes to the field level (Wallingford, 2003).

Each farm has 6 plots, arranged horizontally. The left-most watercourse would first serve Farm 1 Plot A, followed by Farm 2 Plot A, through to Farm 5, Plot A. Irrigation would then continue to Farm 1 Plot B on to Farm 5 Plot B, through Tertiary 2, and so on. In any given irrigation turn, a farmer could have to come back up to six times to irrigate his farm. This operating pattern is matched by the design of the infrastructure, which has division structures at each level to ensure accurate provision of the proper discharge to each area.

Irrigation efficiency at plot level is 70% (that is, the fraction of applied water used by the crop), but that system efficiency is below 50% (that is, the fraction of water diverted to an irrigation system actually beneficially used by the crop). This means that canal system efficiencies are also 70%, which is surprising because the system is for a large part lined, well constructed and well maintained. It may be that operational losses (that is, the mismatch between delivery schedule and the pattern of demand) account for much of the measured 'inefficiency', and that such losses are returning to drains and hence re-used elsewhere. The fact that aquifers are generally declining and large-scale water logging is not reported suggests that to the extent that there are losses, these are already being substantially exploited through local re-use (by pumping from drains or aquifers). The issue is important given the claim that reducing losses may improve availability - a claim that holds only if 'losses' are not already recaptured (Wallingford, 2003).

The irrigation system has accurate distribution and measuring structures, as the concept of water scarcity was already dominant in the original design of the irrigation system in Morocco.

2.4 Institutions and governance

The Ministry of Public Works has overall responsibility at national level for water resource development.

Morocco's nine major irrigation systems are operated by ORMVAs - semi-autonomous regional public institutions responsible for agricultural development (both irrigated and rainfed), including irrigation design, O&M, and fee collection. About 1000 people are working at the l'ORMVAT (400 on water management, 300 on extension and 300 on administrative tasks).

The ORMVAs are hierarchically organised. At the top is a Board chaired by the Minister of Agriculture, members are representatives of farmer organisations and the Ministries of Finance, Commerce, and Interior, amongst others. Next are the regional Technical Committees, chaired by District Governors. Finally, at the local level (3,000-4,000 ha), Agricultural Development Commissions are responsible for irrigation planning.

The ORMVAs' financial resources come from fees paid by users, particularly irrigation water fees, and from state subsidies - investment subsidies and/or subsidies to balance operating budgets. An ORMVA accountant (who works for the Ministry of Finance) is responsible for water fee collection. There are two forms of recovery:

- Recovery at source. This method applies to farmers who have production contracts with agro-industrial units, such as a cotton or sugar mill. Here, the mill pays the ORMVA any water fees due, before paying the farmer for his crop.
- Direct payment. Farmers are individually invoiced every quarter using a customer code, with invoices delivered by the ditch-rider (Aiguadier). Payment is due twice a year. Farmers who settle their dues promptly receive priority treatment from the ORMVA; penalties in case of late/non-payment are: after 1 month, suspension of supply; after 2 months, an 8% increase in the amount due; after 1 year, there should be a court action. In reality many farmers are, however, disconnected (instead of any court action).

In Tadla, each farmer has a 'cheque book' of water consumption. For each water turn the farmer completes a 'cheque' for the ditch rider, keeping a copy for his records.

While the total water available to each farmer for the season is defined, the schedule of deliveries is variable, based on individual demand (within reason and subject to competing demands at the same time). The cheque book keeps a running account of the total water used. This approach is an innovative means of combining rationing with flexibility.

At the beginning of the 1990s, the government responded to rising O&M costs of irrigation infrastructure with a new policy - Participatory Irrigation Management, giving farmers a greater role in irrigation management, primarily in order to reduce costs. A law announced in 1990 provided a legal basis for establishing Water User Associations (WUAs), with responsibility for managing irrigation systems. Tadla now has registered 29 WUAs (11 in Beni Amir and 18 in Beni Moussa), representing 41% of farmers in an area covering 44,540 ha.

The purpose of establishing WUAs was to provide a structure for involving water users in the water allocation via the board members of the WUA's and management as well as maintenance of irrigation systems. However, the new organisations did not prove a success. WUA board members tended to maintain irrigation infrastructures. Many farmers did not trust or lost trust in the WUA organisation and refused to pay special charges for keeping the WUA organisation. In Tadla, farmers also showed little inclination to clean secondary and tertiary canals themselves in return for a reduction in water fees, because fees were relatively low (fees are intended to be reduced by 20% if farmers operate and maintain tertiary canals; 40% if they also clean secondary canals) (Papin, 2003). (See Section 3.1.) Water users denounced their WUA Board, and most WUA's have not been active other than being listed on paper. The failure of WUAs essentially precludes meaningful Participatory Irrigation Management.

The ORMVA of Tadla (ORMVAT) allocates water to farmers on the basis of a bulk water volume assigned to each perimeter for each agricultural season. This bulk water volume is decided in consultation with the watershed agency, taking into consideration the water demand of all the irrigation perimeters concerned. ORMVAT then draws up a projected schedule of irrigation over a year-long period. Normally, water is allocated to farmers on a per-hectare basis.

The quotas for canal water are quantified by farm -seasonal allocation depending on availability-and measured close to the point of delivery. The limitation of water use provides and incentive for users to avoid waste and irrigate crops with a high return to water. It provides a transparent means of allocating water, ensuring that consumption of water is controlled, and making farmers individually appreciate that water is scarce.

In times of water scarcity - which is often the case -, priority is given by the ORMVAT to irrigate certain crops. The result then is that access to water is controlled. According to Papin (2003), priority is given to perennial crops (to avoid too long a water shortage, and loss of a valuable investment), second to cereals (to maintain the production of certified seeds) and), third to alfalfa (to ensure fodder for livestock) and fourth to sugarbeet (to maintain local sugar refineries). The priority crops do also not receive full water requirements in dry years. The other crops may even receive less than 3000 m^3/ha (in that case farmers also pay less).

The ORMVAT is not responsible for groundwater management. The River Basin Agency (l'Agence du Bassin Hydraulique) is responsible. They judge requests for licences to extract groundwater on the basis of extractions from surrounding wells. Water is currently extracted from about 10,000 private wells, whereas officially there are only 600 wells – a trend that has increased over recent years in the face of regular drought. The majority of pumps are powered by diesel engines. There is surface drainage.

3. Price, costs and value of water ($ 1=8.9 MAD)

3.1 Price paid for canal and tubewell water

Canal water fees are based on the Agricultural Investment Code of 1969 - a general law organising agricultural water management, water pricing and service fee recovery. The Code provides a comprehensive cost recovery structure, including full recovery of operational and maintenance costs (through water fees) and partial (40%) recovery of capital costs (through the water fee), indexed over time to inflation. Water is charged on the basis of quantity received - metered in the case of the pressurised systems and calculated on the basis of time and the nominal flow rate for surface systems. Water fees can be raised on the basis of a more than 5% overall increase in costs due to increased cost of irrigation equipment, operation and maintenance costs, or fluctuations in the exchange rate. The new price must be approved by the Ministers of Public Works, Agriculture and Finance as well as by the parliament.

It should be noted that the objectives of water charging policy in Morocco - recovering 40% of capital costs, in addition to all annual O&M costs - are ambitious and have yet to be met. Acutal water charges in Morocco are: (1) relatively high by international standards; (2) charged according to the volume of water delivered (although payment for a basic allocation of 3,000m^3/ha is obligatory); and (3) seen by government as a mechanism to encourage appropriate resource allocation through discouraging unproductive use.

In Tadla, the canal water fee in 2002 was $ 0.02/m^3- the lowest in Morocco because, unlike other areas, Tadla canal systems do not involve lifts (in some regions the rate is as high as $ 0.062/m^3). Nonetheless, the canal water fee in Tadla has shown a steady increase over time, from $ 0.005/m^3 in 1980 to $ 0.01/m^3 in 1987/88 and $ 0.015/m^3 in 1992 (see El Yacoubie and Belghiti, 2002). In regions where pumping is a significant part of operational costs[1], farmers do not pay the full O&M costs. Here the ORMVA relies on an annual transfer of funds from the central government in order to meet operational expenses, while farmers are not charged for capital costs.

Pumping of groundwater from wells is a private undertaking of the farmer. Well-owners pay the full cost of development and O&M - apparently often preferring diesel because of the high cost of electricity, though it may be that it is difficult to obtain an electrical connection for an unauthorised well. Most pumps have a discharge of 15 l/s (54 m^3/hour) and consume 2 l/hour of oil for groundwater in the aquifer rises till 20 m below field level (amounting to $ 1.3/hour). The energy cost for groundwater is thus $ 0.024/m^3. Total cost of groundwater extraction including energy costs, amortisation and pump maintenance costs, is $ 0.045/m^3. This means that the costs for well water are higher than the

[1] Electricity is charged to ORMVAs at 20% below the commercial rate - around 0.08 $/kwh.

costs of canal water. Another negative element of well water is the relatively high salinity content which restricts the exclusive use of well water.

3.2 Costs of water delivery

The cost of providing irrigation services in Tadla, are summarised in Table 1 and Table 2. Annual O&M costs are $ 11.5 million for an area of 92,000 ha, which is $ 125/ha/yr. Annual full costs are $ 13.5 million for an area of 92,000 ha, which is $ 147/ha/yr including depreciation on capital. This relatively small difference between O&M and full costs is because Tadla is an older project - the first irrigation project built in Morocco - and was (in current prices) therefore comparatively cheap at the time of construction. It requires, however, more maintenance. For a water delivery of 7,400 m^3 per ha, O&M costs are $ 0.017/m^3 and full costs are $ 0.02/m^3. This means that there is only a small difference between O&M ($ 0.017/m^3) and full costs ($ 0.02/m^3).

Table 1 Annual O&M costs including labor (without capital depreciation) in million $

	Dept of irrigation and drainage		Dept of construction		Dept of agri. development and extension		Total	
	Amount	%	Amount	%	Amount	%	Amount	%
Direct costs	4.1	70	0.5	68	3.3	69	8.0	69
Indirect costs	1.8	30	0.2	32	1.5	31	3.5	31
Total costs	5.9	100	0.8	100	4.8	100	11.5	100

Table 2 Annual total costs (with capital depreciation) in million $

	Dept of irrigation and drainage		Dept. of construction		Dept of agri. Development and extension		Total	
	Amount	%	Amount	%	Amount	%	Amount	%
Direct costs	5.4	71	0.6	69	3.5	70	9.5	71
Indirect costs	2.2	29	0.3	31	1.5	30	4.0	29
Total costs	7.6	100	0.9	100	5.0	100	13.5	100

Official statistics indicate that current water charges cover even more than O&M costs (Table 3), which is consistent with the estimated farm payment for water ($ 145-155/ha). Current water charges cover even more than O&M costs. If full water fee collection is achieved, i.e. if all uses pay there debts in Tadla, more than 100% of O&M expenditures are covered. The data indicate that system delivery losses (between diversion and measurement to farmers) are relatively low, because the volume of water billed at the farm level is 80% of water available to the scheme.

Table 3 Budget and expenditures in $

Year	96/97	97/98	98/99
Provisional budget	11,954,205	10,493,814	10,218,438
Actual expenditure on operations	10,355,227	9,089,175	9,040,417
Pumping costs	161,250	135,361	138,854
Maintenance	58,182	100,206	86,563
Personnel	6,325,682	5,567,629	5,584,896
Other operations costs	3,810,227	3,286,082	3,230,104
Actual expenditure on new investment	901,136	2,342,474	2,401,667
Total actual expenditure	11,256,364	11,431,649	11,442,083
Income (recovery from fees)	13,322,500	12,264,948	14,293,125

3.3 Value of water

This section applies a consistent analytical framework to assess the contribution of water to various levels of production (returns to water). Appendix F1 shows the results of a farm survey for three farms in Tadla, ranging in size from 4.8-7.7 ha. The first three tables show farm income assuming that irrigation is fully from canal water. The last three tables show farm income assuming that irrigation is fully from groundwater. In fact, many farms use a mixture of sources.

The main crops grown include wheat (for seed multiplication), fodder crops (alfalfa, berseem) and olives. This reflects the priority given to strategic crops by the government when irrigation water is scarce (see Section 2.4) - and government influence over cropping patterns. Returns to wheat and broadbean are relatively high compared to the returns to lucerne, which may be explained by the relatively low market price due to internal deliveries as lucerne is often used as fodder for livestock. Appendix F1 shows that net returns to water in Tadla is about $\$ 0.10/m^3$. It is an indicator for the contribution of water to production.

Key data for this study, summarised in Table 4, are gross income per hectare; net income (before water charges); and the proportion of net income (before deduction of water charges) accounted for by water charges, assuming charges are paid in full.

Table 4 Summary data for Tadla

Farm	1	2	3
Size (ha)	4.8	6.0	7.7
Gross Income ($/ha)	1,453	1,971	318
Net income before water charges ($/ha)	901	1,470	612
Water charge if 100% canal $/ha (% of net income)	156 (17%)	145 (10%)	145 (23%)
Water charge if 100% well $/ha (% of net income)	320 (35%)	297 (20%)	298 (49%)
Actual % of net income spent on water	35%	17%	35%

These summary data indicate that farmers in Tadla spend a substantial proportion of their income on canal irrigation services 10-23%, and even more on groundwater 20-49%. As they use a mixture of both sources, they actually spent about 17-35% of their net income on water.

3.4 Discussion of price, costs and value of water

The O&M cost of water delivered at the field in Tadla is \$ 0.017/m^3, while full costs are \$ 0.02/m^3. The current volumetric canal water fee is relatively high \$ 0.02/m^3 and covers the O&M costs, but is substantially less than the returns to water \$ 0.1/m^3. As farmers spend a substantial proportion of their income on canal water, it is likely that current prices give an incentive to reduce usage. The present level of the charges will not achieve a balance between supply and demand, but is sufficiently high to discourage wastage and to concentrate usage on water-productive crops.

4. Recommended policy instruments

This section evaluates the potential role of economic instruments to achieve policy objectives in Morocco. The analysis of the preceding sections suggests that main policy objectives with respect to irrigation water management in Morocco are (in order of priority):

- to balance supply and demand of groundwater;
- to reduce overall water consumption in agriculture;
- to increase the productivity of water; and
- to increase cost recovery.

Groundwater

Establishing sustainable groundwater extraction depends on balancing the supply and demand of groundwater. Existing policies (restricting pumping to over 40 m below soil surface) and requiring authorisation to install wells are not very effective due to insufficient enforcement. The administrative costs of charging for extraction on the basis of the number of pumping hours - as currently proposed - are likely to be high, and will not guarantee a reduction in usage (although such a positive price will give an incentive to reduce usage). Another possibility - recommended here - would be to define entitlements for groundwater use, which do currently not exist. This would restrict total groundwater demand even in dry years (when farmers can pay a considerable price). So a rationing system for groundwater use is recommended, which can be enforced.

Canal water

Water charges are currently used primarily (and quite successfully) for cost recovery and only to a limited extent as an instrument for demand management. The positive marginal price of canal water (through the volumetric charge) provides some incentive to reduce water consumption, but current charges do not reflect the marginal value of water use (charges are only one-fifth of the estimated average value of water), as rationing is currently governing demand. The present system of charging for canal water would not - in the absence of rationing - achieve a balance between supply and demand, but charges are sufficiently high to discourage severe wastage, and to concentrate usage on more water-productive crops. A considerable increase in the price of water would be needed to balance the supply and demand of canal water. However, such increases would lead to a drastic fall in income and might be socially unacceptable, and render some crop uncompetitive. Morocco has a Code specifying ambitious volumetric water charging policies, however, the full water charges implied by the Code have never been collected, as it is politically unfeasible. The government is aware of the role water charges can play in reducing demand. However, there is an obvious wariness to take on the political risk entailed in raising water charges.

The challenge is therefore to find a balance between treating water as an economic good and as a social good. One solution is to adopt a mixture of private and public tools to achieve objectives relating to productivity and equity: for instance, water uses that have a high value but low ability to pay could get a refund for social reasons for example. Block rate pricing is socially more acceptable, but the transaction costs seem to be high (may even exceed the efficiency gains). Another threat posed by raising canal water fees is that such an increase is likely to prompt increased use of groundwater. Rationing is therefore a more suitable instrument to govern demand.

It is, however, interesting to note in this respect that big landowners are rather creative in dealing with the current rationing system. They grow sugar beet to get priority in water allocation. In practice they under irrigate the sugar beets and use the water for non-prioritised crops.

Equally, volumetric water charges do not ensure appropriate cost revenue levels. In a dry year when there is limited water to sell, revenues will fall proportionately. In a year of high rainfall, demand for irrigation water will be limited, again leading to revenue shortfalls. In addition, only part of water charges are recovered as 3-10% of farmers currently do not pay their water bill.

Economic incentives have so far failed in Tadla to encourage water users to participate in water management, including remission of water fees in exchange for farmers maintaining irrigation systems. It is important to note in this respect that all the required institutions should be in place. WUA are for instance more developed in some ORMVAs and less in others. This means that there are differentiated policies for WUAs among ORMVAs, but there are no differentiated institutions. There is for instance still no legal framework that allows WUAs to collect fees.

Tadla in Morocco is the most sophisticated of the surface irrigation systems studied, but still uses rationing to constrain demand. Volumetric water charges are used to achieve cost recovery, which is relatively high. Volumetric charging will continue to play a role in encouraging productive use of water, but volumetric allocations are likely to remain the dominant means of ensuring that demand is constrained to equal supply. It should be noted that to overcome the constraints of inflexibility and the quantity of surface water availably, many farmers have invested in private tubewells, where the unit price of water is more than double that of surface supplied. To control groundwater use, it is recommended to define entitlements for groundwater use in Tadla. Another solution to declining groundwater levels would be to forbid pumping when groundwater levels fall below a certain threshold level.

5. Conclusions

The availability of water is, and will continue to be, the key factor constraining agricultural production in Tadla. Deteriorating water quality strengthens this concern. The scarcity of canal water and the significant exploitation of groundwater in dry years has prompted several policy objectives: to balance supply and demand of groundwater, to reduce overall water consumption in agriculture, to increase the productivity of water, and to increase cost recovery.

It has become clear that the volumetric canal water fees currently charged in Tadla \$ 0.02/m^3 cover O&M costs, but are less than the return to water \$ 0.1/m^3. Such a positive variable price of water gives incentives to increase the productivity of water and to reduce water consumption, but is relatively small compared to the value of water and can therefore only play a limited role in balancing supply and demand of canal water.

Balancing the supply and demand of canal water would require a considerable increase in the price of water. However, this is not desirable for two reasons. First, an increase in the price of canal water is politically sensitive. Second, such an increase could trigger an increase in the use of groundwater. Therefore rationing, which is already used in Tadla, seems a more suitable instrument to govern demand for canal water with the additional benefit of low transaction costs.

Balancing the supply and demand of groundwater would require that entitlements to groundwater use are clearly defined, establishing a valuable institutional structure for the overall management of water. The total number of entitlements will be limited and therefore usage will be constrained to sustainable availability. It will restrict total groundwater demand even in dry years (when farmers can allow to pay a considerable price for water). A volumetric groundwater extraction charge will not guarantee a reduction in usage. As in the case of surface water, the charge would have to be extremely high to balance supply and demand.

Under the current system in Morocco, the regional ORMVAT is responsible for the distribution and allocation of water, from the principal canal down to individual farms, and for maintaining the system. The ORMVAT also collects water fees, and plays a role in planning cropping patterns and providing agronomic advice.

It has been argued that the cost of the various tasks carried out by the ORMVATs could be reduced by giving farmers a greater role in operating and maintaining irrigation systems, by means of Participatory Irrigation Management. In Tadla, however, O&M costs are relatively low. As a result, the incentive offered to farmers to participate (a remission of water fees) is of limited value. Such a transfer of tasks is therefore not interesting from an economic point of view, but Tadla is not a representative perimeter in this respect (given its relatively low O&M costs).

So, Morocco is currently using very suitable instruments already -rationing and some volumetric charging- to govern demand for canal water and to recover O&M costs. Attention needs, however, to be paid to policies to control groundwater use in an effective way. It is recommended to ration groundwater demand by defining entitlements for groundwater use.

References

Ait Kadi, M, *Irrigation water pricing policy in Morocco's large-scale irrigation project*s. 2002.

El Yacoubie, Z. and M. Belghiti, *Water valuation, the case of Morocco, valuation of irrigation water in Morocco.* Ministry of Agriculture, Rural Development and Forestry, Rural Engineering Administration, Development and Irrigation Management Department, Beirut, Lebanon. 2002.

Herzenni, A, *Enjeux de la GPI (gestion participative de l'irrigation) au Maroc. Cas de la grande irrigation*. 2001.

Papin, C., *PIM in Tadla: Policy and field reality: a case study of the Beni Amir irrigation scheme, Tadla Region, Morocco.* MSc Thesis, Wageningen University. 2003.

World Bank, *Morocco at a glance.*
(http://www.worldbank.org/data/countrydata/aag/mar_aag.pdf). 2003

Wallingford, *Water charging in irrigated agriculture-lessons from the field.* 2003.

Appendix F1 Overview of outcome of the spreadsheets

Table F.1 Tadla Farm Budgets - Canal Irrigated

Farm 1 -- 4,8 ha

	Income per ha	Crop Area	Farm Income	COSTS			Net Income	Family Labor		Water		
				Inputs	Labor	Water		Use	Return	Use	Return $/m3	
	$	ha	$	---------- $ ----------			$	(days)	$/day	000 m3	Gross	Net
Sugarbeet	1.060	1,0	1.058	443	165	155	**295**	59	5	7,8	0,1	0,1
Wheat	2.680	0,8	2.135	195	25	64	**1.851**	22	83	3,2	0,7	0,6
Lucerne	1.080	1,8	1.944	1.466	48	415	**15**	53	0	20,7	0,1	0,0
Broadbean	1.645	0,6	987	60	6	43	**878**	27	33	2,2	0,5	0,4
Olive 1	920	0,6	552	68	86	52	**345**	21	16	2,6	0,2	0,2
Berseem	498	0,6	299	69	21	21	**189**	5	35	1,0	0,3	0,2
	Totals	5,4	6.976	2.301	352	750	**3.573**	188	19	37,5	**0,2**	**0,1**
Cropping Intensity = 112%			Utilization of Available Family Labor =78%				Proportion of Family Labor in Total Used = 70%					

Farm 2 -- 6 ha

	Income per ha	Crop Area	Farm Income	COSTS			Net Income	Family Labor		Water		
				Inputs	Labor	Water		Use	Return	Use	Return $/m3	
	$	ha	$	---------- $ ----------			$	(days)	$/day	000 m3	Gross	Net
Sugarbeet	1.400	2,0	2.772	1.062	506	308	**895**	74	12	15,4	0,2	0,1
Wheat	2.033	2,0	4.025	421	147	160	**3.298**	34	97	8,0	0,5	0,4
Broadbean	1.410	1,0	1.404	102	60	72	**1.170**	47	25	3,6	0,4	0,3
Paprika	2.600	1,0	2.590	442	9	203	**1.936**	3	565	10,1	0,3	0,2
Olive 2	1.040	1,0	1.036	83	178	127	**648**	26	25	6,4	0,2	0,1
	Totals	6,9	11.827	2.110	900	870	**7.947**	184	43	43,5	**0,3**	**0,2**
Cropping Intensity = 116%			Utilization of Available Family Labor =77%				Proportion of Family Labor in Total Used = 46%					

Farm 3 -- 7,7 ha

	Income per ha	Crop Area	Farm Income	COSTS			Net Income	Family Labor		Water		
				Inputs	Labor	Water		Use	Return	Use	Return $/m3	
	$	ha	$	---------- $ ----------			$	(days)	$/day	000 m3	Gross	Net
Sugarbeet	600	1,5	901	672	4	234	**8-**	118	0-	11,7	0,1	0,0
Wheat	1.550	3,4	5.251	664	28	273	**4.286**	84	51	13,7	0,4	0,3
Lucerne	480	2,6	1.246	1.543	14	598	**909-**	245	4-	29,9	0,0	-0,0
Broadbean	1.410	0,2	271	26	0	14	**231**	9	25	0,7	0,4	0,4
	Totals	7,7	7.669	2.905	46	1.118	**3.600**	456	8	55,9	**0,1**	**0,1**
Cropping Intensity = 100%			Utilization of Available Family Labor =63%				Proportion of Family Labor in Total Used = 97%					

Table F.2 Tadla Farm Budgets - Groundwater Irrigated

Farm 1 -- 4.8 ha

	Income per ha $	Crop Area ha	Farm Income $	COSTS Inputs $	COSTS Labor $	COSTS Water $	Net Income $	Family Labor Use (days)	Family Labor Return $/day	Water Use 000 m3	Water Return $/m3 Gross	Water Return $/m3 Net
Sugarbeet	1,060	1.0	1,058	443	165	318	**132**	59	2	7.8	0.1	0.1
Wheat	2,680	0.8	2,135	195	25	132	**1,784**	22	80	3.2	0.7	0.6
Lucerne	1,080	1.8	1,944	1,466	48	850	**-420**	53	-8	20.7	0.1	0.0
Broadbean	1,645	0.6	987	60	6	89	**832**	27	31	2.2	0.5	0.4
Olive 1	920	0.6	552	68	86	106	**291**	21	14	2.6	0.2	0.2
Berseem	498	0.6	299	69	21	43	**167**	5	31	1.0	0.3	0.2
Totals		5.4	6,976	2,301	352	1,538	**2,785**	188	15	37.5	**0.2**	**0.1**

Cropping Intensity = 112% Utilization of Available Family Labor =78% Proportion of Family Labor in Total Used = 70%

Farm 2 -- 6 ha

	Income per ha $	Crop Area ha	Farm Income $	COSTS Inputs $	COSTS Labor $	COSTS Water $	Net Income $	Family Labor Use (days)	Family Labor Return $/day	Water Use 000 m3	Water Return $/m3 Gross	Water Return $/m3 Net
Sugarbeet	1,400	2.0	2,772	1,062	506	631	**572**	74	8	15.4	0.2	0.1
Wheat	2,033	2.0	4,025	421	147	327	**3,130**	34	92	8.0	0.5	0.4
Broadbean	1,410	1.0	1,404	102	60	147	**1,095**	47	23	3.6	0.4	0.3
Paprika	2,600	1.0	2,590	442	9	416	**1,723**	3	503	10.1	0.3	0.2
Olive 2	1,040	1.0	1,036	83	178	261	**514**	26	20	6.4	0.2	0.1
Totals		6.9	11,827	2,110	900	1,783	**7,034**	184	38	43.5	**0.3**	**0.2**

Cropping Intensity = 116% Utilization of Available Family Labor =77% Proportion of Family Labor in Total Used = 46%

Farm 3 -- 7.7 ha

	Income per ha $	Crop Area ha	Farm Income $	COSTS Inputs $	COSTS Labor $	COSTS Water $	Net Income $	Family Labor Use (days)	Family Labor Return $/day	Water Use 000 m3	Water Return $/m3 Gross	Water Return $/m3 Net
Sugarbeet	600	1.5	901	672	4	479	**-253**	118	-2	11.7	0.1	0.0
Wheat	1,550	3.4	5,251	664	28	560	**3,999**	84	48	13.7	0.4	0.3
Lucerne	480	2.6	1,246	1,543	14	1,226	**-1,537**	245	-6	29.9	0.0	-0.0
Broadbean	1,410	0.2	271	26	0	28	**216**	9	23	0.7	0.4	0.4
Totals		7.7	7,669	2,905	46	2,293	**2,425**	456	5	55.9	**0.1**	**0.1**

Cropping Intensity = 100% Utilization of Available Family Labor =63% Proportion of Family Labor in Total Used = 97%

Appendix G Ukraine - Crimea[1]

Abstract
After the collapse of the Soviet Union -central planning system- in 1991, the sustainability of irrigation is endangered due to the disappearance of agricultural markets and transitional problems. The slow privatisation process and -undefined transition state of ownership- as well as the lack of farmers funds for maintenance results in the breakdown of irrigation equipment and the actual acreage under irrigation decreased drastically. A decline in water demand in return requires still higher prices to recover costs from the smaller 'sales' based. The limited demand for water creates a vicious circle of low revenues as demand is low, poor financial viability, inadequate maintenance and consequently deteriorating irrigation equipment. Policy should therefore change from 'preserving the traditional way of irrigated agriculture' towards 'stimulation of irrigation for all users'.

1. Introduction

In 2002 Ukraine had a population of 48.7 million - decreasing at - 0.8 % per year- of which 32% lives in rural areas. Agriculture accounts for 16.9% of GDP. Gross Net Income per capita is $ 770 (World Bank, 2003). Crimea is an autonomous Republic, situated in the south (see Figure 1).

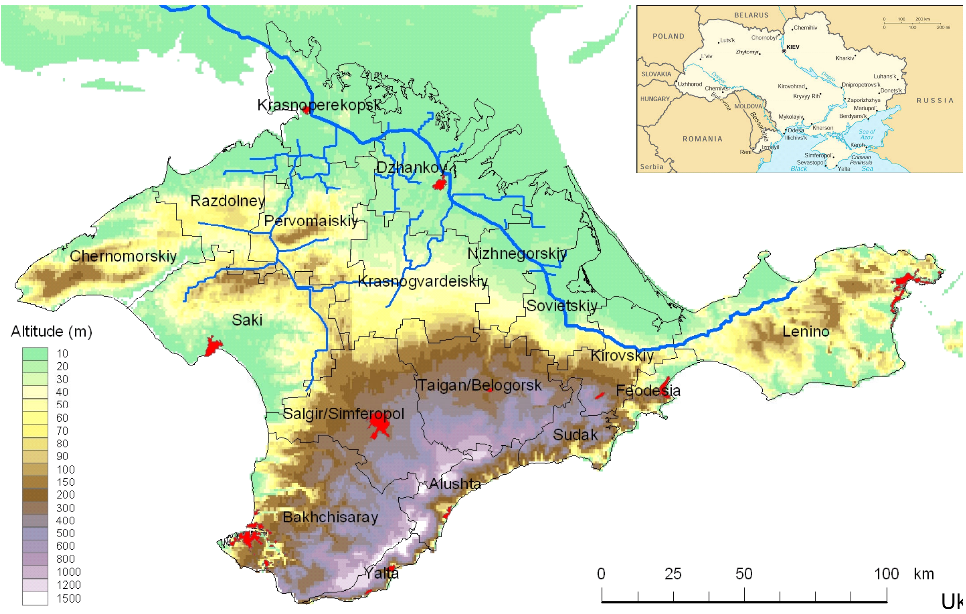

Figure 1 Location of Crimea and NCC irrigation system in the Ukraine

[1] This paper is written in the framework of WATERMUK2.

Crimea has a population of 2.1 million of which 38% lives in rural areas. Total size of Crimea is 2.6 million ha, which is 5.3% of the Ukraine. The territory of Crimea can be divided into a northern and central flat part (80% of Crimea) and southern – mountain (20%). Agricultural land occupies 71% of the total area. Precipitation is annually 400mm on average, but in the central part it is 360 mm. In the growing season it is only 250 mm, and covers only part of crop requirements as evapotranspiration is 1,000mm on average (Tischenko, 2003).

The deficit of water resources in Crimea is covered mainly by delivery of water from the Northern Crimean Canal (further NCC), which was constructed during the early sixties to deliver water from the Dnieper River to Crimea. The main canal is 402 km long and serves 370,000 ha with water. It is designed for a maximum discharge of 300 m^3/s. The main user of water from NCC is agriculture (87%, water is mainly used for irrigation), but it also serves municipalities (9%) and industry (4%). The infrastructure was designed for irrigating large fields of state-owned and collective farms (2000-5000 ha each). The main on-farm irrigation application technology is sprinkler machines, which irrigate 50-200 ha each.

After the collapse of the Soviet Union -central planning system- in 1991, the sustainability of irrigation is, however, endangered due to the disappearance of markets for agricultural products. Besides, the guaranteed market for inputs disappeared. Insufficient performance of the Ukrainian banking sector caused barter trade and payment of salaries in kind to become more the rule than the exception. The lack of markets and entrepreneurship has reduced farms' funds to buy inputs and maintain equipment the last decade, which reduced outputs.

Collective ownership and control of production factors had to be replaced by the notion of individual ownership. Privatisation of collective farm land and irrigation equipment has not yet been completed. This slow pace of transformation and -undefined transition state of ownership- endangers the sustainability of irrigation. The irrigation systems and their users are not adapted to the new economic situation. To overcome the mismatch between the present large-scale field irrigation equipment and the scale of the farms after privatisation, people have to collaborate. They are willing to do so, but it is hard to find reliable partners.

This requires modernisation (a new design of the irrigation system) rather than rehabilitation (replacement of the irrigation system). Farmers are currently not able to fund modernisation. They are often even not able to maintain the system or do not feel responsible, due to a lack of well-defined property rights of assets. It is even not clear whether farmers can recover the operation costs of delivery. In large parts of the command area of NCC the water has to be lifted several times before it reaches the field, and associated energy costs are high.

The bad performance of the irrigation systems in Crimea is not only a technical problem, but mainly a socio-economic problem. For the modernisation of the irrigation systems a healthy and sustainable irrigated agricultural sector is required, which depends on the profitability of irrigation in the future. Irrigation is profitable when the benefits, i.e. returns to water, exceed the costs, which does not only depend on irrigation costs but also on crop yields and prices.

During the transition period the actual acreage under irrigation and consequently irrigation water delivery decreased drastically, which resulted in under-utilisation of the system. The year 2003 is used as base years for this analysis. Precipitation water approximately 400 mm in 2003, but it was very dry in spring (only about 120 mm during the critical period). According to official records of the irrigation authorities the actual acreage under irrigation in Crimea was 209.9 thousand ha and irrigation water delivery was 740.3 million m^3 in 2003. There are, however, doubts about the reliability. According to official reports the irrigated area in Dzhankoy in 2003 was for instance 31.2 thousand ha, whereas actual irrigated area based on gathered information about irrigation technologies shows a significantly lower figure of only 18 thousand ha. The latter figure was validated by staff of the Irrigation Department (ID) and by means of remote sensing image monitoring. The bias in irrigated area may be explained by the fact that it is in the interest of the ID and SCWM of Crimea and Ukraine to over estimate figures as their budget is dependent on the irrigated area.

2. Water problems, policies, infrastructure and institutions

2.1 Water problems and policy objectives

The bad performance of the irrigation systems in Crimea, such as the breakdown of irrigation equipment and large operational losses that damage the environment, is mainly due to the problems that farmers face as a result of the collapse of the Soviet Union. It is therefore not a water resource management problem, but mainly a socio-economic financial transitional problem. Figure 2 relates the various problems that arise in Crimea. It shows that current water problems are mainly caused by transitional problems as described below.

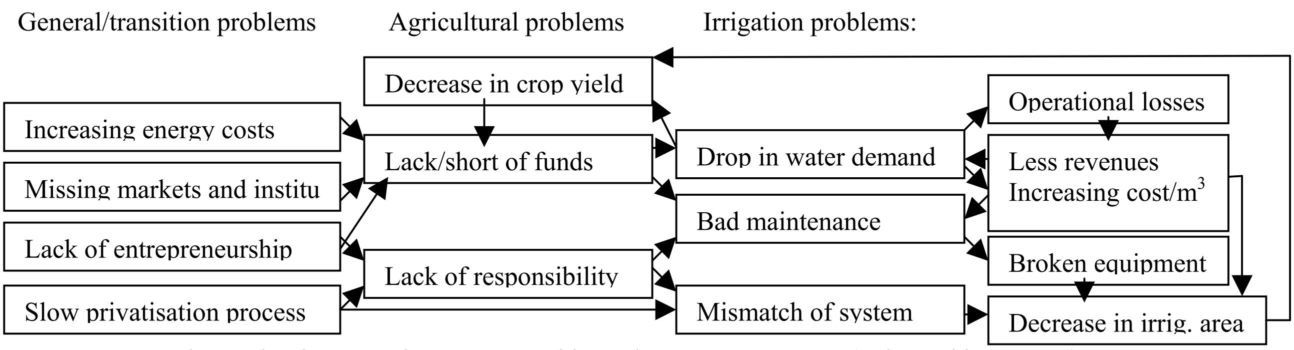

Figure 2 Relationship between the various problems that arise in Crimea (indicated by arrows)

- First of all, due to a decline in demand water availability currently exceeds demand and higher charges are required to recover costs from the smaller 'sales' based. Irrigation of fodder crops reduced for instance from 1,900 to 1,000 m^3/ha between 1995 and 2003. Besides electricity costs increase over time; in 1998, 1999, 2000, 2001 and 2002 it was respectively 0.017, 0.023, 0.028, 0.039 and $ 0.051/KWh. During Soviet times 70% of agricultural products were produced on irrigated lands, whereas it is now only 15 -35% (Zhumagulova, 2003).

- Second, the required maintenance costs are currently often not recovered as a result of a lack of funds due to missing markets, which resulted in the breakdown of irrigation equipment.
- Finally, it is likely that there will be sometimes a mismatch between the scale of the irrigation system and the scale of the farms after privatisation (one irrigation machine to serve up to 20 future farmers), which requires modernisation. Capital cost for rehabilitation and/or modernisation are currently not covered. The financial sustainability (instead of water scarcity) is therefore the main problem. The main policy objectives are therefore to stimulate irrigation for all users, re-establish the financial viability of irrigation schemes.

2.2 Existing policy instruments

The main regulatory document on water use and protection in Ukraine including the regulation of irrigation is the Water Code of Ukraine adopted by the Verkhovna Rada of Ukraine and introduced from the 6th of June 1995. Till December 1999 transformations were, however, weak. The decree of the President of Ukraine accepted in December 1999 'About urgent measures on acceleration of reforming of agrarian sector of economy' considerably accelerated the speed of the transformation process. According this decree between December 1999 and April 2000 collective agricultural enterprises (kolkhoz) have to be reformed to private companies. The water usage in Ukraine is regulated by the Law of Ukraine 'On the Protection of the Environment'. Allocation and effective utilisation of land plots under irrigation are regulated by the Code of Land Laws of Ukraine.

Land reform in Ukraine begins when land is denationalised and ownership is given to the transformed collective farms. In the second stage farm members receive their right to land and property shares. Property is allocated differently than land. Property shares are calculated based on the individual's tenure and salary level. The third stage of land reform envisions new collective enterprises evolving into joint-stock, reformed collective, or other ownership enterprises that operate on the basis of private land ownership. The majority of Ukraine's farms have been officially transformed into joint-stock companies called collective agricultural enterprises. They have undergone little change in management, production choices, or resource allocation. Most large-scale farms are unprofitable and have large debts, but at the same time the best irrigation performance can be observed at the large-scale farms.

Currently, there are volumetric water charges, which are differentiated by crop, district, kind of contract and location of the farm (see Section 3.1). Since 2001 farmers have to make pre-payments for electricity delivery to the ID. The same principle functioned already since 1999 between ID and Republican Electro Energy Stations. A lack of funds in the beginning of the irrigation season for such payments is one of the reasons that demand for water has reduced. The situation has improved since 2003, the year with lowest yields for rainfed winter grains in history. The government supports irrigated agriculture by refunding the main part of electricity cost of irrigation.

2.3 The irrigation infrastructure

NCC irrigation system management consists of three levels:

- Management Department of NCC, managing the main canal and transfer pumping stations;
- 13 Irrigation System Departments (ISD) in Crimea (and 5 in Kherson region), managing the secondary canals and systems;
- Farms, managing their on-farm irrigation canals and systems.

The main canal is divided into five parts by four main pumping stations, and each part has different costs due to the increasing slope of land to the southeast (the last pumping station is not under the responsibility of NCC, but of Kerch city). Water has to be lifted several times. The self-running water -over a distance of 208 km from Kahovska reservoir- is lifted by the first pumping station up to an altitude of 9 meters. Since 1998 the amount of water lifted by this pumping station reduced from 70 to 35 m^3/s, due to decreasing demand. The other three pumping stations lift up water to an altitude of 14, 27 and 54 meters, which implies that costs increase as water is lifted by respectively 9, 5, 13 and 27 meters.

Total water delivery by NCC was 1345 million m^3 in 2002. From this volume about 1060.7 million m^3 reaches the Crimean border, which is allocated as follows: 788.9 million m^3 is delivered before the first pumping station, 193.4 million m^3 between the first and second station and 43.5 million m^3 between the second and third station and 34.9 million m^3 after the third station. This means that the first pumping station pumped 271.8 million m^3 of water, the second 78.4 million m^3 and the third 34.9 million m^3. The fourth pumping station supplies drinking water to Kerch city, the organisation and costs involved is its own responsibility.

2.4 Institutions and governance

The institutional set-up of water management in the Ukraine is rather complex. Water management is based on a combination of three different principles: (1) basin management, (2) canal management and (3) management on the base of the state administrative regions. The system is very centralised and major decisions and coordination between the institutions are made on a very high level: by the State Committee of Water Management of Ukraine (SCWM of Ukraine), The Cabinet of Ministers or by the President of the republic. There are 4 Basin Departments of Water Management (BDWM), 5 Canal Management Departments (CMD) and 24 Regional Departments of Water Management (RDWM) and the SCWM of Crimea (which was in the past the RDWM). Within the RDWM there are a number of district Irrigation Departments (ID) according to the state administrative division of regions. Within the system there are also a lot of very narrow specialised organisations on district, regional and national level. Totally there are 263 organisations hierarchically and administratively managed by the SCWM–Ukraine (for an overview of the institutional set-up see Pavlov, 2004). To provide insight into the water management in Ukraine, a more detailed description is given below of the main institutions at the national level (SWCM of Ukraine), Canal level (CMD), Crimean level (SWCM of Crimea), District level (ID) and farm level.

The SCWM of Ukraine is the central executive authority in water management. It belongs to the Ministry of Environment and activities are coordinated by the Cabinet of Ministers. In its activities it obeys the constitution and laws of Ukraine, acts of the President of Ukraine, the Cabinet of Ministers of Ukraine, and its by-law. Primary tasks of the committee are to: 1) develop and realise the state policy for water management and land reclamation; 2) participate in realisation of programs of use, protection and reproduction of water resources; 3) realise inter-basin redistributions; 4) realise actions for prevention of harmful actions.

The mandate of the Canal Management Department (CMD) is operation and management of the main NCC. The department has five sub-departments situated along the canal. It operates the three main lifting pumping stations. The CMD of NCC planes and distributes the water to the irrigation departments and other water users. The day-to-day delivery is based on orders from users according to the yearly plan for water delivery. This plan is made in the beginning of the irrigation season according to the plans of the IDs and the SCWM of Crimea and is approved by the SCWM of Ukraine. IDs are reporting for water used to the CMD of NCC every 6 hours. As the system is quite flexible and there is no water scarcity, there are currently no technical problems between the CMD and IDs or SCWM of Crimea. There is, however, some misunderstanding with respect to payment for water delivery.

The SCWM of Crimea is, according to its statutes, an authorised institution of the Ukrainian state executive authority in the field of use, protection and reproduction of water resources (previously it was the RDWM). Primary tasks of the committee are to: 1) realise state policy; 2) establish operation regimes of water basins; 3) design, construction, O&M of water systems; 4) conduct the state account of water use and the state water cadastre; 5) co-ordinate licensing for water rights; 6) realise radiological and hydro-chemical monitoring of reservoirs; 7) prevent negative water influence to the environment.

The main activity of the ID is delivery to farms of a certain quantity of irrigation water of the required quality at the right time. Water delivery is carried out on the basis of the annual contracts signed between ID, farms and Drainage Department. The contracts are on water delivery, drainage and maintenance on inter-farm irrigating and drainage networks.
In 2003 Dzhankoy ID had 107 contracts for water delivery. The contracts are with 27 large collective farms, 9 private farms and 71 small farm associations (incl. peasants and tenants).

The large collective farms inherited from the Soviet time are now called Agrarian Joint-Stock Company with Limited Responsibility (AJSC Ltd). Kolkhozes are transformed to enterprises based on private land ownership shares. They have, however, not changed a lot in structure, management, crop pattern etc. The size varies between 2,000 and 5,000 ha in Dzhankoy. Employees are shareholders and contracted personnel. The number varies between 300 and 800. Machinery is in bad condition and it is still not clear how it will be transferred to private property. The rent to the shareholders is often paid in kind and payments are often postponed. They use on-farm pumps operated by the ID and farmers consequently pay 10 UAH/1,000m^3. They receive subsidies for the electricity for water delivery from 2003 onwards.

Private farms (or family farms) are potentially flexible in crop choice (currently choice is limited due to absence of irrigated lands) and are more market oriented. The size is 100-200 ha, about half is owned by family members and the rest is rented. The main work force is family labour plus some contracted employees. The staff varies between 7-15. There is no specialisation of the workers. The head of the family is often the main manager. Sometimes private farms use their own mobile pumps and rent irrigation machines from collective farms. There are all kinds of contracts with the ID for water delivery and prices consequently vary.

Small farm associations consist of 5 to 20 privatised peasants that aim to improve effective farming, mainly by minimizing costs. Members act together for receiving land ownership certificates and have one contract with the ID. In most cases, they have constructed their own private water intakes. Peasants are shareholders of land who have taken out their land from collective farms and started farming on their own. The size of plots is between 3- 5 ha.

In Ukraine water is a public property were the state institutions hold the right over water resources. As water rights exist in bureaucratically managed irrigation system, the practice of water distribution refers directly to the rights in detail (delivery schedule, type of crops, etc.). The Water Code of Ukraine regulates the normative framework of water rights in the country. The procedure for receiving water rights is complex and bureaucratic. Water users have to present 12 different documents coordinated by different institutions before they get a license (Pavlov, 2004). It is difficult for small farmers to go through these procedures, as each document has to be paid. Farmers therefore form associations to use one 'water right' license and to minimise the costs. According to the Water Code water rights are issued for periods up to 25 years. In practice the period is, however, often only 1 to 3 years. Under such uncertainty farmers cannot make long-term plans and investments in infrastructure and machinery.

A transfer of responsibilities from the State to the farmers takes place, but many farmers are not capable of it due to a lack of management experience and bad farm practice is the result. There is also still hardly any participation of farmers in irrigation management. Farmers sign a standard contract with the ID for water delivery and are not involved in off-farm water management activities. There is no control by farmers of the ID with respect to the efficiency of O&M and financial aspects. Although farmers have the right to receive such information, it is hardly used except for information on electricity spend on on-farm pumping stations. Participation of farmers is important to bridge the gap between control and monitoring. It can have a positive impact on transparency, services, accountability and may reduce conflicts.

3. Price, value and costs of irrigation water ($ 1=5.2 UAH)

3.1 Price paid for canal water

Volumetric irrigation water charges for agricultural purposes in the various irrigation districts in 2003 are shown in Table 1. It shows that volumetric water charges for rice are relatively low (< $ 0.0005/m^3), whereas charges for other crops are about $ 0.002/m^3.

Table 1 Price of irrigation water delivery, irrigated area and water delivery (including rice) in 2003

Irrigation District (source of irrigation)	Water charge ($/1000m^3)		Irrigated area (1000 ha)	Irrigation water delivery/sales (million m^3)	Number of pumping stations	Number of pumps
	Other crops	Rice				
Bakhchisaray (reservoir)	1.83		6.9	4.1	1	5
Dzhankoy (NCC)	1.92	0.38	31.2	55.3	70	301
Kirovskiy (NCC)	1.96		5.0	2.2	13	59
Krasnogvardeiskiy (NCC)	1.92		31.0	55.2	37	152
Krasnoperekopsk (NCC)	1.92	0.19	24.9	316.6	25	82
Lenino (NCC)	5.77		2.7	1.8	13	39
Nizhnegorskiy (NCC)	2.25	0.48	17.4	94.3	24	96
Soedenitelniy canal			1.8	4.0	11	59
Pervomaiskiy (NCC)	1.92		19.5	30.8	32	121
Razdolney (NCC)	2.23	0.48	17.6	109.3	38	189
Saki (NCC)	1.35		25.1	17.7	43	189
Salgir/Simferopol (reservoir, NCC)	2.02		8.8	8.0	13	54
Sovetskiy (NCC)	2.50	0.42	11.3	26.6	15	66
Taigan/Belogorsk (reservoir)	2.12		6.7	14.4	2	8
Averge/Total	2.31	0.38	209.9	740.3	337	1420

Charges vary not only by district and crop, but also by the kind of contract and location of farms in relation to their type of water intake (Pavlov, 2004). Five different water tariffs can for instance be distinguished within the administrative borders of Dzhankoy District in 2003 (Table 2). The way these tariffs are derived is explained in Appendix G1. On 90% of the irrigated area under control of the Dzhankoy ID, the charge of 1.92 $/1000m^3 was paid. Table 2 shows that farms with private -often temporary- intakes pay a higher charger than farms with state-owned pumping stations. Both pay, however, less -in the case of gravity flow- than the required budget, which implies there is no full cost recovery.

Farm subsidies have not been taken into account in Table 2. In principle every farm can receive a refund of electricity costs for irrigation purposes. Depending on the conditions of the particular year, a refund of 50% to 100% of these costs is paid by the Ministry of Agriculture and the ID. Mainly large former collective farms receive such subsidies for the following reasons (i) only state-owned pumping stations can measure electricity use accurately, (ii) most private intakes (siphon or diesel pump) do not use electricity, and (iii) a bank account is required to transfer refunds, which most small farms do not have.

Table 2 Price of irrigation water ($/1000m^3) in Dzhankoy district in 2003

Farm water intake	Water price
State-owned pumping station (O&M by Dzhankoy ID)	1.92*
Rice canal intake (O&M by Dzhankoy ID)	0.38
Private intake with private pump (O&M by private farmers)	3.46
Private intake with siphon (O&M by private farmers)	7.31
Direct contracts with NCC	4.05

*Electricity costs of the ID for operation of the state-owned pumping stations will be added.

3.2 Value of water

Returns to water will vary not only among crops and years (as required water quantities vary due to weather influences), but will also depend on the irrigation technology used to apply water and will even depend on the farming practice (like timing of application).

Average returns to water, i.e. values of water, are based here on the difference in benefits minus costs of crop production between irrigated and rainfed land divided by the quantity of irrigation water applied (Zhovtonog et al., 2004). Table 3 shows average returns to water with a probability of respectively 10%, 50%, 75% and 95% to have a dry year for grain maize, winter wheat and fodder maize for various irrigation technologies. The table shows that returns to water vary largely and that returns to water are usually higher, if there is a small probability to have a dry year (i.e. when there is only a small quantity of water required)[1]. Returns to water for winter wheat using Fregat with 50% probability to have a dry year are $ 0.11/m^3.-

Table 3 Returns to water ($/m^3)

	Grain maize				Winter wheat				Fodder Maize			
	10%	50%	75%	95%	10%	50%	75%	95%	10%	50%	75%	95%
Surface	0.18	0.11	0.10	0.06					0.17	0.13	0.11	0.09
Fregat	0.32	0.19	0.19	0.13	0.28	**0.11**	0.09	0.09	0.30	0.22	0.20	0.17
DDA	0.27	0.16	0.16	0.10	0.21	0.07	0.06	0.06	0.25	0.19	0.16	0.14
Kuban	0.20	0.13	0.15	0.09	-0.10	-0.01	0.01	0.02	0.12	0.14	0.14	0.13
Hose pipe	0.18	0.10	0.11	0.06	-0.06	-0.02	-0.01	0.00	0.12	0.11	0.11	0.09

3.3 Costs of water delivery

A distinction is made here in the actual irrigation expenditures on water delivery including on-farm pumping station expenditures (Table 4) and the potential estimated irrigation costs on water delivery excluding on-farm pumping station costs (Table 5). Irrigation expenditures and costs are shown at irrigation district level in Figure 3 and 4. The tables show that potential irrigation costs per 1000 m^3 (Table 5) are in almost all districts lower than actual expenditures per 1000 m^3 (Table 4) as there is not only an increase in the required budget (as potential costs exceed actual expenditure), but also an increase in water delivery (as potential delivery exceeds actual delivery). It is, however, important to note that costs of on-farm pumping stations are not included in Table 5, whereas they are included in the expenditure of Table 4.[2]

[1] Field experiments of Tischenko (2003) validate that returns to water of winter wheat for the first 200 m3 of water irrigated are indeed relatively high. Over a period of six years with winter wheat, the first 200 m3 of water irrigated in addition to 2000 m3 from rainfall will give an additional yield of 23 %. When respectively 1000, 1500, 2000 and 2600 m3 is irrigated the additional yield will be 75, 91, 97 and 100%.

[2] Potential irrigation costs for Dzhankoy including on-farm pumping costs are 0.012 $/m3 (as the required budget is 2792,800 $/yr). It consists of 0.008 $/m3 for energy, 0.001 $/m3 for salary, 0.001 $/m3 for repairs and 0.002 $/m3 for others. These potential irrigation costs including on-farm pumping costs are, however, still smaller than actual expenditure including on-farm pumping costs.

Table 4 Actual irrigation expenditures for NCC and for secondary canal systems plus on-farm pumping stations in the Crimean irrigation districts in 2003

	Delivery	Budget	Energy	Salary	Repairs	Other	Total
	Million m^3	$ 1000/yr	$ 1000/m^3	$ 1000/m^3	$ 1000/m^3	$ 1000/m^3	$/$m^3$
NCC	857.3	2713.7	1.7	0.6	0.3	0.6	0.003
Dzhankoy	55.3	988.9	7.9	8.1	0.4	1.5	0.018
Kirovskiy	22.0	459.6	10.0	7.1	0.3	3.5	0.021
Krasnogvardeiskiy	55.2	1908.4	27.4	5.3	0.6	1.4	0.035
Krasnoperekopsk	33.7	520.9	3.4	8.4	0.8	2.9	0.016
Lenino	1.8	137.6	11.7	47.2	3.1	14.5	0.077
Nizhnegorskiy	94.3	329.6	0.9	0.5	1.1	1.0	0.004
Soedenitelniy	108.9	1848.9	13.6	2.4	0.6	0.3	0.017
Pervomaiskiy	30.8	782.9	14.4	8.7	1.0	1.4	0.025
Razdolney	110.9	546.8	1.8	2.4	0.2	0.5	0.005
Saki	57.7	580.2	4.4	5.0	0.7	0.0	0.010
Salgir/Simferopol	22.8	379.3	3.3	6.8	0.6	5.9	0.017
Sovietskiy	26.6	212.1	1.1	5.6	0.3	1.0	0.008

Table 5 Potential irrigation costs for NCC and for secondary canal systems in the Crimean irrigation districts

	Potential Delivery	Required Budget	Energy	Salary	Repairs	Other	Total
	Million m^3	$ 1000/yr	$ 1000/m^3	$ 1000/m^3	$ 1000/m^3	$ 1000/m^3	$/$m^3$
NCC	1232.4	5991.9	3.4	0.6	0.2	0.7	0.005
Dzhankoy	240.4	1647.7	2.3	0.3	0.7	3.6	0.007
Kirovskiy	54.6	459.6	0.0	0.0	0.0	8.4	0.008
Krasnogvardeiskiy	151.2	3549.3	13.0	0.6	2.1	7.8	0.023
Krasnoperekopsk	123.3	557.3	0.0	0.1	0.3	4.1	0.005
Lenino	21.6	137.6	0.0	0.0	0.0	6.4	0.006
Nizhnegorskiy	104.8	331.1	0.0	0.0	0.0	3.1	0.003
Soedenitelniy	148.7	3089.3	11.2	0.6	4.9	4.2	0.021
Pervomaiskiy	115.0	825.9	0.0	0.3	0.3	6.6	0.007
Razdolney	134.0	614.6	0.0	0.3	0.5	3.9	0.005
Saki	156.5	588.3	0.0	0.0	0.0	3.7	0.004
Salgir/Simferopol	66.7	379.3	0.0	0.0	0.0	5.7	0.006
Sovietskiy	64.3	212.1	0.0	0.0	0.0	3.3	0.003

Table 6 shows the fixed and variable on-farm costs (which are not included in Table 5) of the various irrigation technologies. Fixed costs (investment and fixed maintenance costs) are high for Kuban, drip and hose pipe. Variable costs (including energy, petrol and labour) are high for DDA and hose pipe. Total costs per volume required decrease with a higher net water requirement. On-farm costs vary among districts due to the composition of farmers' irrigation technologies in each district. On 84% of the irrigated area in Dzhankoy sprinklers are for instance used, on 12% furrow, on 3.5% surface irrigation and on 0.5% drip irrigation.

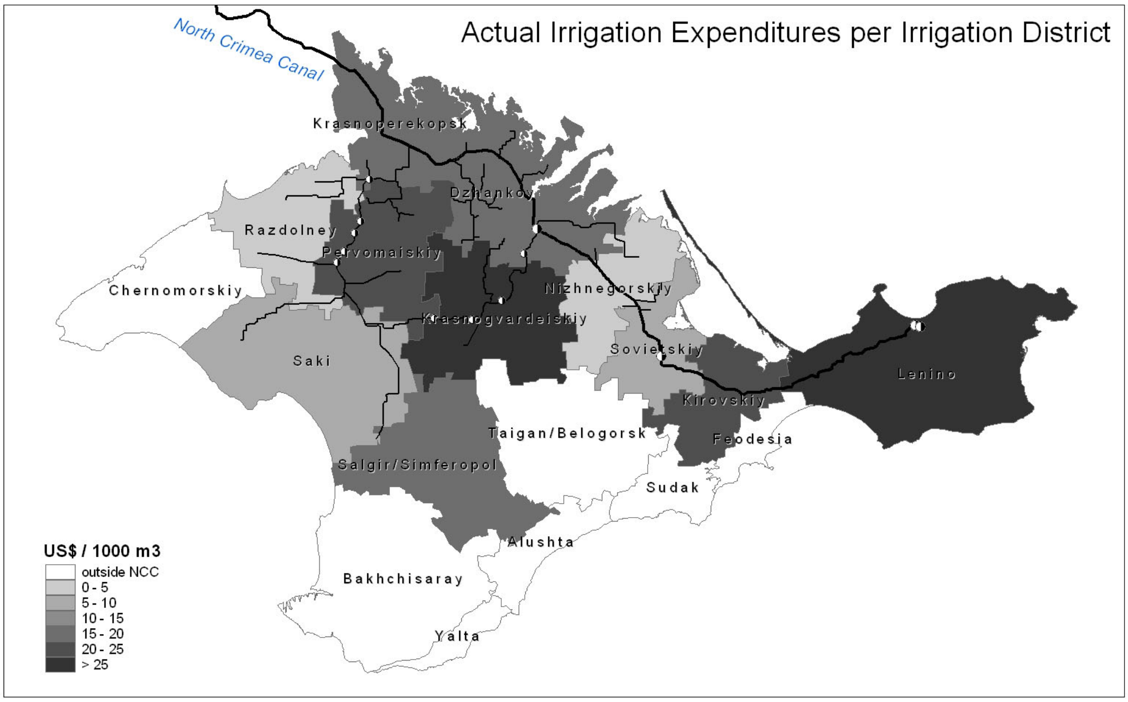

Figure 3 Actual Irrigation Expenditures per Irrigation District

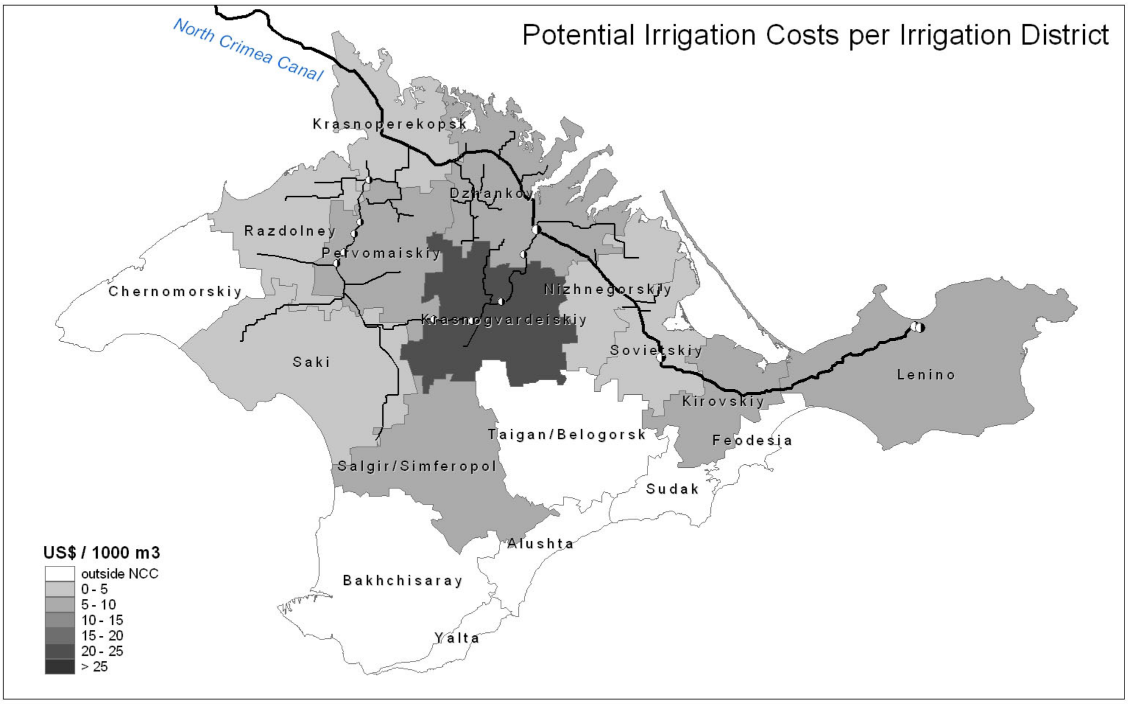

Figure 4 Potential Irrigation Costs per Irrigation District

Table 6 Costs of the various on-farm irrigation technologies (including equipment, canals, etc)

Technology	Fixed Costs ($/ha/yr)	Variable costs ($ 1000/m^3)	Irrigation efficiency (%)	Total costs for net 1000m^3 ($/m^3)	Total costs for net 2000 m^3 ($/m^3)	Total costs for net 3000 m^3 ($/m^3)
Surface	80	20	50	0.120	0.080	0.067
Mechanised surface	85	20	50	0.125	0.083	0.068
Fregat	90	8	80	0.100	0.055	0.040
DDA	110	25	70	0.146	0.091	0.072
Kuban	300	6	80	0.308	0.158	0.108
Drip	600	6	90	0.607	0.307	0.207
Hose pipe	250	40	70	0.307	0.182	0.140

The fixed costs of fregat consists of $ 11/ha for the irrigation network, $ 23/ha for machines, $ 6/ha for pump station equipment and $ 50/ha for fixed maintenance costs. The variable costs of fregat consist mainly of energy costs. Total costs per hectare to provide a certain net crop irrigation water requirement depend also on the irrigation efficiency (part of water intake by on farm pump station utilised by the crop) and increase when more water is required (see Figure 5). It becomes clear that Fregat is relatively cheap.

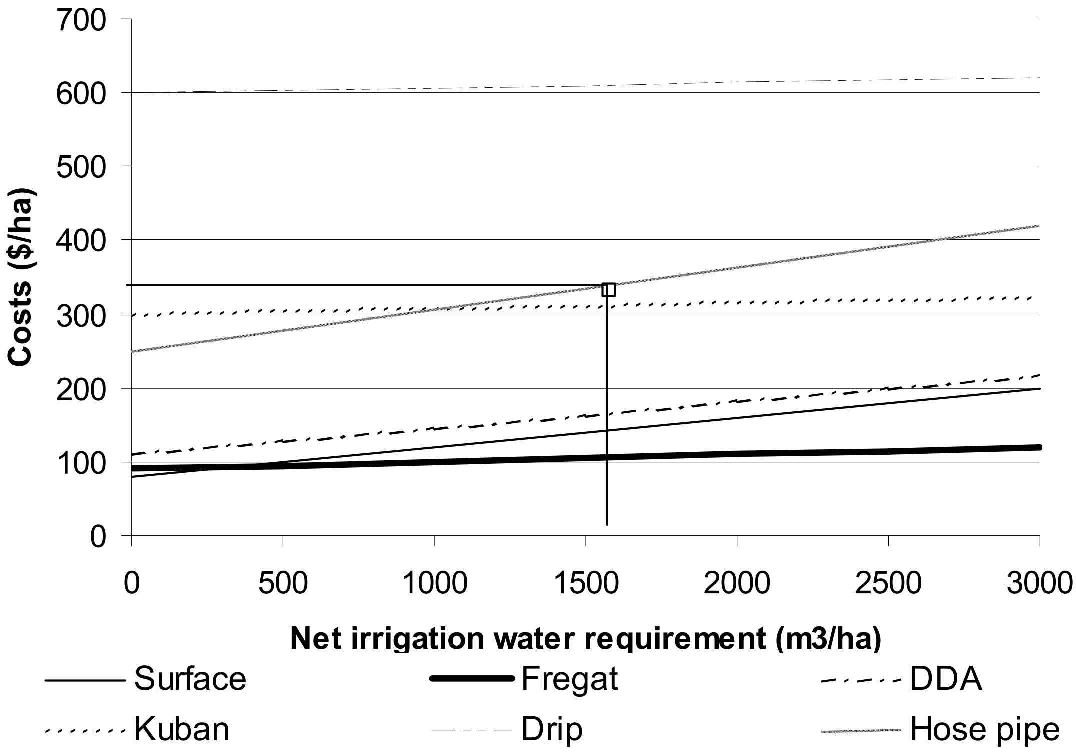

Figure 5 Costs of the various irrigation technologies to provide a certain net water requirement

Break-even costs
The irrigation costs that equals the benefits of irrigation are the so-called break-even costs of irrigation. Benefits of rainfed winter wheat are for instance $ 264/ha and growing costs $ 242/ha, whereas benefits of irrigated winter wheat are $ 654/ha and growing costs $ 298/ha (excluding irrigation costs). This means that break-even cost of irrigation of winter wheat are $ 334/ha. Figure 5 shows that drip and hose pipe exceed these break-even costs.

Table 7 Net water requirement (m^3) and break-even irrigation costs ($/ha) including costs of delivery

Crop	10% probability		50% probability		75% probability		95% probability	
	m^3/ha	$/ha	m^3	$/ha	m^3	$/ha	m^3	$/ha
Grain maize	1,400	682	2,500	744	3,300	948	3,600	733
Spring barley			600	140				
Sunflower	1,000	266	1,900	247	2,700	288		
Winter wheat	500	280	**1,600**	**334**	2,200	372	2,500	430
Alfalfa	2,800	477	3,700	502	4,800	539	5,100	550
Fodder maize	1,000	487	2,000	692	2,800	840	3,100	824
Fodder beet	2,300	748	3,000	665	3,900	701		
Vegetables	1,900	1630	2,600	5071	3,500	4830	3,800	4709

3.4 Discussion of price, costs and value of water in Dzhankoy

The charge for irrigation water delivery is approximately $ 0.002/m^3 in Dzhankoy in 2003 (Table 2), while expenditure on water delivery for NCC, secondary canal system and on-farm pump stations is $ 0.021/m^3 (Table 4). This means that only 10% of current expenditures on water delivery is covered in the water charge. Potential cost of water delivery till farms' border for NCC and secondary canal system are $ 0.012/m^3 (Table 5). Total costs (including on farm-costs) are $ 0.067/m^3 when fregat delivers 2000 m^3 of water (at a cost of $ 0.055/m^3), but exceed $ 0.1/m^3 when DDA is used. This implies that on-farm costs have a substantial share (more than 75%) in total costs.

Table 8 Charge paid, actual expenditures, potential costs and returns to water ($/$m^3$) in Dzhankoy

Water charge		Total expenditures incl. NCC		Costs till farms' border incl. NCC		Total costs		Returns to water
0.002	<	0.021	>	0.012	<	0.067	<	0.11

Unambiguous statements about the profitability of irrigation are hard to make, given the large variation in both total costs (which mainly depend on the irrigation technology used and irrigation water requirement) and returns to water (which varies among crops and years). In 2003 crop prices were for instance relatively high: $ 180/ton for winter wheat, $ 120/ton for winter barley and $ 135/ton for potato, but yields were also lower and more water was used as it was a relatively dry spring and summer. Profitability of irrigated agriculture will also change over time due to the transition from a central planning to a market economy. Nevertheless it is clear that returns to water are considerable, but on-farm costs as well. Costs of water vary not only among districts, but also within districts.

Cost-recovery

Partial recovery of costs by farmers can be justified as water used for irrigation can be a powerful means of reducing food costs. Irrigated agriculture may also support economic development in rural areas, providing jobs and supporting agro-food industries in areas, which should otherwise become depopulated. This explains why the government sometimes subsidises those uses of water that have a high social value to the government, but low ability to pay. It is therefore a challenge to identify the right balance between water treated as an economic good (water user pays) and water treated as a social good (government pays part of it).

Additional costs -not quantified here- are costs of environmental damage and modernisation of the irrigation system. This means that costs are even higher than estimated here. It is recommended to estimate the costs to solve the mismatch between the scale of the present large-scale field irrigation equipment and future farm size as well as costs of environmental damage due to irrigation in order to provide insight into the full-costs of irrigation. It is, however, not so easy to derive the costs of environmental damages, as wetlands are not marketed.

3.5 Sensitivity analyses

As the on-farm costs have a rather substantial share in total costs, the sensitivity of the results to some of the assumed values of on-farm costs and benefits will be studied here. The impact of 40% lower and 40% higher values of the market price, water price and electricity price as well as crop yield and the fixed irrigation costs on the on-farm returns to water is studied in this section. The case of irrigation of winter wheat using Fregat with 50% probability to have a dry year is taken as a reference in Figure 6.

The steeper the line the more sensitive (responsive) returns to water to higher/lower values. Figure 6 shows that the returns to water are most sensitive to the winter wheat crop market price (a correction is made for additional fertiliser costs for each extra ton) and to crop yield. Returns to water are less sensitive to the fixed and variable irrigation costs (like water price and electricity price).

The returns to water in the future will therefore mainly depend on the future development of the crop market price for winter wheat. For winter wheat the world market price has varied between \$ 100-240/ton with \$ 140/ton on average over the last 10 years, whereas in the analysis a market price of about \$ 100/ton is used. When farmers can sell at a market price of \$ 140/m^3 returns to water will exceed \$ 0.18/m^3. It is therefore recommended to study future agriculture policy in the Ukraine, especially export and import policy of agricultural products.

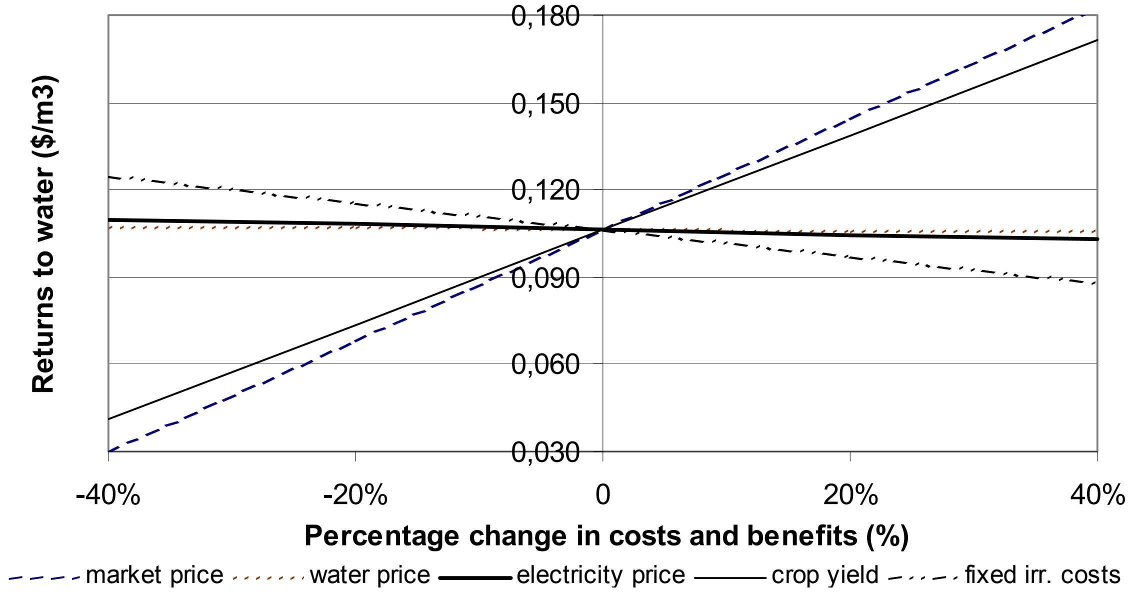

Figure 6 Sensitivity of the returns to water

4. Recommended policy instruments

Based on the analysis in Sections 2 and 3, the current policy of the Government and water authorities at all levels (SCWM-Ukraine, SCWM-Crimea, ID) can be characterised as 'to maintain and preserve the traditional way of irrigated agriculture', with the main objective to preserve the integrity of the large-scale infrastructure of farms, fields and irrigation infrastructure. Other reasons are the fear that with the real privatisation of the collective farms also the social infrastructure will collapse, whereas no practical experience exists in other forms of management than the traditional hierarchical top-down management.

Dhzankoy ID tries to create equal conditions for all water users (it uses its own vision for the current situation), but (i) formally temporary small private users pay higher water charges, (ii) mainly farms that use state-owned pumps are subsidised by refunding the pumping electricity costs, (iii) it is very bureaucratic and expensive to obtain a water right for new water-users and (iv) there is still hardly any participation of farmers.

One can argue the effectiveness of the current policy. It is not based on generally accepted principles like equity, cost-recovery, democracy, flexibility and sustainability. The actual result of this can be observed nowadays: irrigation decreased dramatically since 1990 and the majority of the large collective farms is still not viable. Therefore it is proposed to base the irrigation policy on the following principles:

- Equity. Water charges should be equal for all agricultural users. Currently, the farms with private water intakes pay part of the costs of water delivery of farms with state-owned pumping stations. The equity principles should also be applied on subsidies.
- Cost-recovery. In a market economy, which Ukraine is, cost-recovery should form the basis for the calculation of the water price. This is currently, however, not the

case. The volumetric water charge to farmers is for example based on the amount of water delivered to the ID, and not on the amount of water sold to the farms (see Appendix G1). Costs of losses are consequently not recovered. Along with cost-recovery goes cost reduction. The following mechanisms can be applied: (i) concentrate on the core business (for ID this is water delivery) and reduce staff and parts of the organisation, which do not belong to the core business, (ii) cost charging at all levels; not only farmers should pay for irrigation water, also the ID should pay the NCC management for the receipt of water; this forms an incentive to reduce wasteful use of water and thus costs and (iii) the budget that the government provides to the ID should no longer be based on/related to the irrigated area, to avoid a bias in the actual and official irrigated area. It is recommended to fix the government budget on a certain level, which forms an incentive for the ID to reduce cost without loosing budget.

- Accountability. It is recommended to create accountability from the authorities to the water-users. Since farmers pay part of the irrigation costs they should be able to influence and control also the executive authorities (ID). To start this participatory process, one can think of the formation of a steering group of water-user representatives, who should approve the yearly budget and policy of the ID.
- Flexibility. To reverse the process of decreasing irrigation, the use of irrigation water should be stimulated. Therefore the ID management should be more flexible to anticipate to user circumstances and wishes. Mechanisms for this purpose are (i) to make water rights easier to obtain, especially for the privatised farmers and (ii) to facilitate besides volumetric water charges also crop-based charges.
- Sustainability. The main problem for Sivash wetlands is currently the lack of a system to monitor various kinds of polluting inflows, especially water flows of small rivers and clearing beds of drainage canals. As a boundary condition for all future policies and solutions the environmental sustainability should be taken into account.

The points above are recommendations for the irrigation policy at district level. However, it is clear that one has to focus also on agricultural policy reform (land privatisation, market development, farm credits, etc.) to tackle more general problems that farmers face due to the transition. The viability of irrigation depends on uncertainties in the agricultural sector in general. It is essential to put required institutions and markets in place.

To reverse the process of decreasing irrigation, the use of irrigation water should be stimulated which can be achieved in various ways. Firstly, by making water management more flexible to anticipate to user circumstances and wishes. Mechanisms for this purpose are to make water rights easier to obtain, especially for privatised farmers and to allow besides volumetric water charges also crop-based charges (as explained above). Secondly, by reducing uncertainty in agricultural markets (as set out below).

Due to the disappearance of agricultural crop markets there is uncertainty about crop prices, i.e. farmers are not sure whether the product will fetch a fair price when selling it. The farmer is consequently uncertain about the returns to money spend on producing the product. The farmer is certain about the cost of production, but the income from sales is uncertain. As farmers are risk averse, they will lower their expectations of the product price and therefore value water lower.

To avoid the impact of uncertainty on input use (mainly water use), government intervention in the crop market is proposed in this study. It is recommended to define a 'floor' price at which the government guarantees to purchase any production. Farmers will sell in the open market as long as the free market price is above the 'floor' price, but farmers are assured a reasonable price when the free market price falls too far. Such an assured market for outputs will allow farmers to attract cash money to buy inputs for the next season and to pay upfront water charges.

This seems especially valuable for private farms, as they seem to be less able to hedge price fluctuations by storing crops and finding their own sales market than collective farms. Private farms currently sell crops during harvest time when the price of crops is relatively low and can not afford to hold crops back until the price rises. Forward contracts to buy and supply crops would be a useful hedging instrument in this respect, which might encourage water use.

5. Conclusions

In Crimea in Ukraine water availability is not the constraining factor to production and water availability exceeds demand. Financial sustainability is the main problem in Crimea, as it currently endangers the viability of irrigated agriculture. Required maintenance costs are not recovered, which resulted in bad maintenance and breakdown of irrigation equipment and consequently decrease in demand for water. There is a lack of farmer funds for maintenance of irrigation equipment as a result of the disappearance of agricultural markets and transitional problems. A decline in demand in return requires still higher charges to recover costs from the smaller 'sales' based. The limited demand for water creates a vicious circle of low revenues as demand is low, poor financial viability, inadequate maintenance and consequently deteriorating irrigation equipment. It is therefore important to increase demand. Costs will even increase, as modernisation of the irrigation system is required.

When comparing the price, costs and value of water in Dzhankoy it became clear that water charges ($\$ 0.002/m^3$) in Dzhankoy in 2003 do not cover the potential costs of water delivery till farms' border ($\$ 0.012/m^3$). Besides water charges are small compared to the value of water, which means that it is not very likely that charges will affect water demand. Moreover the actual expenditures on irrigation water delivery ($\$ 0.021/m^3$) exceed the potential cost ($\$ 0.012/m^3$) due to the current low demand for water (i.e. small ‘sales’ based). The on-farm irrigation costs have a substantial share (often more than 75%) in total costs, which shows the importance to focus on these costs in particular. Finally, it is interesting to note that there are big differences in the break-even irrigation costs among crops, due to large differences in benefits of irrigation. Some irrigation technologies, especially those with high fixed costs are too expensive for crops with low returns to water.

The potential for an area-based charge should be considered. If all potential irrigators are charged a flat fee to provide basic revenue to the operating agency, plus an additional crop-based fee designed to recover variable costs (energy costs), then the incentive to irrigate is increased (because the marginal cost of irrigating is lowered by area-based charges) and the funding situation of the operating agency is greatly improved. This approach in turn will encourage those with no interest in irrigation to rent their land to those who are.

It is also important to focus on the level of charges. Partial recovery of costs in water charges seems only temporarily justified to get farms of the treadmill of low yields and lack of funds. This is also justified when investments in irrigation meets social objectives.

To reverse the process of decreased irrigation, the use of irrigation water could also be stimulated in other ways. Firstly, by making water management more flexible to anticipate to user circumstances and wishes by means of making water rights easier to obtain, especially for privatised farmers. Secondly, by reducing uncertainty in agricultural markets. Under current policy in Crimea (i) it is very bureaucratic and expensive to obtain water rights and (iii) there is still hardly any participation of farmers in irrigation management. Policy should change from 'maintaining and preserving the traditional way of irrigated agriculture' towards 'stimulation of irrigation for all water-users' in a financial/environmental sustainable way.

Finally, it is important to note that not only water problems should be addressed and tackled, but also the underlying transition problems as the viability of irrigated agriculture depends on uncertainties in the agricultural sector in general.

References

Pavlov, S.S., *Analysis of the irrigation management institutions in the North Crimea Canal Irrigation System, Ukraine.* MSc Thesis. Wageningen University. 2004.

Tischenko, A., *Управление режимами орошения сельскохозяйственных культур по инструментальному методу. [Management of irrigation scheduling of agricultural crops by instrumental method].* Simferopol: Tavriya, 2003 (240 pp).

World Bank, *Ukraine at a glance.*
http://www.worldbank.org/data/countrydata/aag/ukr_aag.pdf. 2003

Zhovtonog, O, V. Polishuk, L. Filipenko, Y. Grin, V. Korunenko and V. Pisarenko, *Irrigation management at farm-level in the Ukraine.* 2004.

Zhumagulova, A., *Irrigation Profitability in Crimean farms, Ukraine: Cost-Benefit Analysis.* MSc Thesis. Wageningen University. 2003.

Appendix G1 Calculation of water charges in Dzhankoy

Five different water tariffs can be distinguished within the administrative borders of the Dzhankoy District in 2003.

- In principle the water tariff in the Dzhankoy ID for 2003 is 10 UAH/1000m^3. The tariff is calculated as the difference between the required ID budget and actual financing from Government (SCWM-Ukraine) divided by the total water delivery to all water users (see Table G1). The resulting 13.90 UAH/1000m^3 for 2003 is reduced to a water tariff of 10 UAH/1000m^3 for social and political reasons. This price is determined by the ID and is based on a compromise between what the ID would like to receive (taking account of payments for delivery services) and what the farms are able to pay (taking account of experiences of previous years). This water tariff is charged to the farms, which make use of the big state-owned pumping stations as farm water intake, which are operated and maintained by the Dzhankoy ID. In most of the cases these farms are the large former collective farms. The electricity costs to operate the pumping station have to be paid to the Dzhankoy ID as well. Since the pumping stations are operated by the Dzhankoy ID all pumping hours and electricity consumption rates are recorded very accurate. Therefore the water fees and the electricity consumption are billed separately and based upon volumetric water delivery.
- The tariff of water for rice is only 2 UAH/1000m^3. The large rice farms are located at the end of canals with gravity flow and the water simply flows to the rice fields by a dense network of open canals. The low water charge can be justified by the large water consumption of rice and the low energy costs and is calculated in Table G1.
- During the transition period of the last ten years, many farm lands have been privatised to small farms (peasant, family or farm associations). The new farms received small lands without irrigation infra-structure. If they were lucky, the farm plots were located along a canal and they could create their own private water intake by a siphon or small (diesel) pump. In this case, volumetric measurements are not possible anymore by the ID. The alternative is a water charge, based upon crop type and irrigated area, which is written down in a contract between the farmer and the ID. Separation between water delivery and electricity costs is also not possible anymore. Therefore the ID calculates an overall water charge, based upon their total budget including all electricity costs. For the Dzhankoy ID the overall water charge for own intake is 38 UAH/1000m^3 (see Table G1). The water charge calculation passes over the fact that most electricity costs are made by the on-farm state-owned pumping stations of other farms and that the private water intake in most cases uses no electricity at all (siphon or diesel pump).
- However, the water charges above are not strictly applied, exceptions can be made. One exception is made for farmers with private water intakes, which don't use any electricity at ID level, i.e. are located before any lift pumping station. Another calculation of the water charges is made excluding the electricity costs, and the water

charge for private intake before a lifting station is 18 UAH/1000m^3 (see Table G1). This price is sometimes also applied to starting farmers or farms in troubles.

- When farmers extract water directly from the NCC main canal 21.06 UAH/1000m^3 is paid directly to the NCC management department, without interference from the Dzhankoy ID. The water charge is calculated by dividing the total government budget for NCC by the total water delivery.

Table G1. Calculation of charges for water delivery to water users in Dzhankoy in 2003

Costs (UAH)	Total	Crop		
		Other crops		Rice
	Without electricity	With electricity	Without electricity	
Difference between required budget and actual financing from Government (SCWM-Ukraine)	1376555	2741612	1323850	52705
Including:				
Salaries (additionally)	382840	367360		15480
Additional allocation on salary and wage	115198	109392		5806
Material, articles and tools	544477	525420		19057
Food	1770	1770		-
Special uniform (clothes)	42655	41155		1500
Transport means maintenance	207178	200028		7150
Communication	2924	2724		200
Other services and costs	37502	36190		1312
Trip costs	6220	6020		200
Electric energy		1417762	-	-
Costs for gas	4968	4968		-
Costs for other public services	682	682		-
Investments in new machines and equipment	21130	19130		2000
Capital reapers costs	9011	9011		-
Delivered water volume (1000 m^3)	99014.7	72663.7		26351
Value added tax (VAT) (20%)	2.32	6.29	3.04	0.30
Cost of 1000 m^3 delivered water including VAT	13.90	37.73	18.22	2.00
Final water charge	10	38	18	2

This table shows that the volumetric charges are based on a planned water delivery volume of 99 million m^3 in Dzhankoy. More than a quarter (28.3 million m^3) of this water is used for environmental purposes. Only 55.3 million m^3 -of the remaining 70.7 million m^3- is sold to farms (see Table 1). This implies large losses of about 15 million m^3. The volumetric water charge to farmers is currently based on planned water volumes, and not on the amount of water sold to the farms. Costs of losses and water used for environmental purposes are consequently not recovered.