8

SWIM Paper

Multiple Uses of Water in Irrigated Areas: A Case Study from Sri Lanka

Editors:
Margaretha Bakker
Randolph Barker
Ruth Meinzen-Dick
Flemming Konradsen

IFPRI

IWMI

SWIM

System-Wide Initiative on Water Management

SWIM Papers

In an environment of growing scarcity and competition for water, increasing the productivity of water lies at the heart of the CGIAR goals of increasing agricultural productivity, protecting the environment, and alleviating poverty.

TAC designated IWMI, the lead CGIAR institute for research on irrigation and water management, as the convening center for the System-Wide Initiative on Water Management (SWIM). Improving water management requires dealing with a range of policy, institutional, and technical issues. For many of these issues to be addressed, no single center has the range of expertise required. IWMI focuses on the management of water at the system or basin level while the commodity centers are concerned with water at the farm and field plot levels. IFPRI focuses on policy issues related to water. As the NARS are becoming increasingly involved in water management issues related to crop production, there is strong complementarity between their work and many of the CGIAR centers that encourages strong collaborative research ties among CGIAR centers, NARS, and NGOs.

The initial publications in this series cover state-of-the-art and methodology papers that assisted the identification of the research and methodology gaps in the priority project areas of SWIM. The later papers will report on results of SWIM studies, including intersectoral water allocation in river basins, productivity of water, improved water utilization and on-farm water use efficiency, and multiple uses of water for agriculture. The papers are published and distributed both in hard copy and electronically. They may be copied freely and cited with due acknowledgment.

Randolph Barker
SWIM Coordinator

SWIM Paper 8

Multiple Uses of Water in Irrigated Areas: A Case Study from Sri Lanka

Editors:

Margaretha Bakker
Randolph Barker
Ruth Meinzen-Dick
Flemming Konradsen

International Water Management Institute
P.O. Box 2075, Colombo, Sri Lanka

The editors: Margaretha Bakker is Associate Expert in the Health and Environment Program at the International Water Management Institute (IWMI); Randolph Barker is SWIM Coordinator and Senior Advisor to the Director General at IWMI; Ruth Meinzen-Dick is Research Fellow in the Environment and Production Technology Division at International Food Policy Research Institute; and Flemming Konradsen is Environmental Health Biologist at IWMI.

The authors: Rekha Mehra is Director of Economic Analysis at the International Center for Research on Women (ICRW); Anneke Van Eijk is Hydrologist at the Government Service for Land and Water Management, the Netherlands; Fuard Marikkar is Consultant, Yutaka Matsuno is Irrigation Engineer, David Molden is Research Leader of the Performance and Impact Assessment Program, R. Sakthivadivel is Senior Irrigation Specialist, Wim Van der Hoek is Research Leader of the Health and Environment Program, and Parakrama Weligama is Consultant/ Agricultural Economist, all at IWMI. The editors Margaretha Bakker, Ruth Meinzen-Dick, and Flemming Konradsen are the other authors.

This work was undertaken with funds specifically allocated to the System-Wide Initiative for Water Management (SWIM) by the Ford Foundation, the Rockefeller Foundation, and the governments of Australia, Denmark, France, Germany, and the Netherlands.

Bakker, M., R. Barker, R. Meinzen-Dick, and F. Konradsen, eds. 1999. *Multiple uses of water in irrigated areas: A case study from Sri Lanka.* SWIM Paper 8. Colombo, Sri Lanka: International Water Management Institute.

/ water management / water allocation / water use efficiency / irrigated farming / water resources development / water policy / water quality / domestic water / water user associations / water rights / gender / case studies / households / pricing / water costs / Sri Lanka/ Kirindi Oya /

ISBN 92-9090-380-5
ISSN 1028-6705

The International Irrigation Management Institute, one of sixteen centers supported by the Consultative Group on International Agricultural Research (CGIAR), was incorporated by an Act of Parliament in Sri Lanka. The Act is currently under amendment to read as International Water Management Institute.

Contents

Figures, Tables, and Boxes

Acronyms

BWMC	Bundala Wetland Management Committee
COFO	Cattle Owners' Farmer Organization
cumecs	cubic meter per second
DCO	Distributary Channel Organization
DWLC	Department of Wildlife Conservation
EC	Electrical Conductivity
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FCG	Field Channel Group
FCS	Fisheries Cooperative Society
FO	Farmer Organization
GVO	Gross Value of Output
ID	Irrigation Department
ha	hectare
ICRW	International Center for Research on Women
IMD	Irrigation Management Division
INMAS	Integrated Management of Major Irrigation Systems
IWRM	Integrated Water Resources Management
kg	kilogram
km	kilometer
KOISP	Kirindi Oya Irrigation and Settlement Project
LB	Left Bank
MCM	Million Cubic Meters
mg/l	milligram/ liter
mm	millimeter
mS/cm	milliSiemens/ centimeter
MSL	Mean Sea Level
mt	metric ton
NGO	Non-Governmental Organization
NVO	Net Value of Output
NWS&DB	National Water Supply & Drainage Board
OFC	Other Field Crops
O&M	Operation and Maintenance
PMC	Project Management Committee
PPM	Parts Per Million
RB	Right Bank
Rs	Sri Lankan Rupees, at time of the study US$1.00 = Rs 58.80
SPC	Subproject Committee
TDS	Total Dissolved Solids
WHO	World Health Organization

CGIAR Centers

CIAT	Centro Internacional de Agricultura Tropical
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maize y Trigo
CIP	Centro Internacional de la Papa
ICARDA	International Center for Agricultural Research in the Dry Areas
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Council for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IWMI	International Water Management Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IPGRI	International Plant Genetic Resources Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
WARDA	West Africa Rice Development Association

Abstract

Water is being transferred out of agriculture to meet the growing demand in other areas, often without an agreement of or compensation to farmers with irrigated land and water rights. Furthermore, there is a failure to recognize that irrigation systems supply water not only for the main fields, but also for domestic uses, home gardens, trees and other permanent vegetation, and livestock. Other productive uses include fishing, harvesting of aquatic plants and animals, and a variety of other enterprises such as brick making. In addition, irrigation systems can have a positive or negative effect on wildlife habitats. Thus, the withdrawal of water affects the rural household, rural economy, and the environment in a number of ways.

This paper argues that to ensure efficient, equitable, and sustainable water use, to reduce poverty and improve the well-being of the community, irrigation and water resources policies need to take into account all uses and users of water within the irrigation system. The multiple uses of water in the Kirindi Oya irrigation system are examined in this paper. An interdisciplinary group of scientists has investigated a number of areas including water accounting, water quality, household water use, the valuing of water for alternative uses, and the complementarities, competition, and conflicts among uses and users.

Among the various management issues and the problem areas identified, the allocation of irrigation water particularly in periods of scarcity, is perhaps the most critical decision and one that has provoked considerable conflicts in the past. The most appropriate water level to be maintained in the tanks is another critical decision, with evidence to suggest that improved management of the tank systems in the wet season could lead to savings of water and expansion of irrigated area in the dry season. Finally, the study highlights the importance of water quality not only for domestic use but also for fishing and wildlife.

Because of the complexity of the issues involved, however, the results of this study must be seen as a first step towards the development of a suitable methodology for studying the range of uses and interactions among them. While the exact uses and users of water and their relative importance will vary from one irrigation system to another, the issues identified in this pilot study of Kirindi Oya have broader implications for water management policies in Sri Lanka and elsewhere. These relate to the allocation of water between irrigation and other sectors; measures of water quality and efficiency of use; and mechanisms to involve all stakeholders in negotiations over water allocation and use.

Multiple Uses of Water in Irrigated Areas: A case Study from Sri Lanka

Margaretha Bakker, Randolph Barker, Ruth Meinzen-Dick and Flemming Konradsen

1. Introduction

The 1990s have witnessed a dramatic shift in the priorities for water resource allocations and development. Irrigation, which was once seen as the essential factor for securing sufficient food production, is now seen as a “low-value” use of water compared to its municipal, industrial, and even the environmental uses. Irrigation no longer receives priority either in the allocation of funds for project developments or in the allocation of water itself. In a growing number of cases, water is transferred out of agriculture to meet the growing demand in other areas, sometimes with compensation for the farmers with irrigated land and water rights, sometimes without their agreement or compensation.

Irrigated agriculture is the biggest consumer of world’s fresh water resources. On a global level, irrigation comprises 72 percent of the average per capita diversions, with industrial and domestic sector accounting for 19 percent and 9 percent, respectively, of the average per capita water diversions (Seckler et al. 1998). However, these figures are misleading since irrigation systems often provide water for many other purposes besides irrigated agriculture. Even within the agriculture sector, irrigation systems supply water not only for the main fields, but also for home gardens, trees, and other permanent vegetation through elevated water tables, and provide water for livestock. Other productive uses include fishing, harvesting of aquatic plants and animals, and a variety of other enterprises such as brick making. Furthermore, irrigation systems are generally a major source of domestic water supply, and can have important environmental functions in supporting plants, birds, and animals. Within some systems, especially in semiarid areas, irrigation water may be the only source of domestic water available to the households. Recognizing the importance of this source to the health and the social well being of the community is essential and a more holistic approach to irrigation water management may provide substantial health benefits. In certain areas, irrigation water may substantially increase the per capita availability of water throughout the year, with an impact of decreasing the prevalence of skin and eye diseases and the incidence of hygiene-related diseases. Hence, it is misleading to equate irrigation only with the agriculture sector, just as it is misleading to equate municipal consumption with domestic water use, since much of municipal water goes for productive enterprises, even gardens and lawns.

Whether or not multiple uses and users have been considered in *ex ante* project assessments, they are generally not included explicitly in the ongoing management of irrigation systems. One reason for this is that most agencies dealing with water resources have only sectoral responsibility to deal with either irrigation or drinking water or industry, or environment. The government as a whole has the responsibility for overall water use, but the implementing agencies have neither the mandate nor the incentive to balance the needs of various users (Yoder 1983; IIMI 1995a).

Taking all uses and users into account, water management could contribute to higher total productivity of irrigation systems. Currently, many irrigation systems are being “modernized” to improve water use efficiency. Measures such as lining canals or implementing rotational water supplies may increase the efficiency of irrigation at the farm or system level, but if the availability of (ground)water is reduced elsewhere, it may reduce the overall output, and hence the efficiency at the system or basin level. In some cases, complementarities between uses may be found, but in many other cases there will be trade-offs between different uses, in either quantity or quality of water, or both (Konradsen et al. 1997).

This paper argues that recognizing the multiple uses of water in irrigation systems is critical for better water allocation policy. The main research hypothesis is that the value of irrigation water for non-crop purposes will be of significant magnitude when compared with the value for use in field crop production.

There are four research issues examined in this report, drawing on evidence from multiple uses of water in the Kirindi Oya irrigation system in Sri Lanka. The first issue focuses on a more accurate assessment of all the uses and users of water in an irrigation system since water in irrigation systems has been undervalued because of the failure to recognize the different uses. This accurate assessment will better inform decisions about allocating water (and financial resources) between irrigation and other uses. Second, an endeavor is made to value these different uses of water. Third, the interactions and conflicts among different sectors and users of irrigation water are identified. For instance, the rehabilitation efforts of irrigation systems will affect the other uses and users of water as well. This raises the question of how to cope with the rising competition for water between multiple kinds of users and allocate the water in ways that are equitable, efficient, and sustainable. Fourth, the fact that the full spectrum of uses of irrigation water changes the institutional picture of water management is recognized. It is no longer only the Irrigation Department (ID), nor even just the farmers who play a role in water management, but a much broader range of stakeholders: men and women, different occupations, and different government departments. Because of the complexity of the research issues involved, it is a challenge to develop a suitable methodology to study the range of uses and the interactions among them. This study has developed a set of methodological tools to define and value multiple uses of water. The objective of this paper is not to present a complete assessment of multiple uses in Kirindi Oya, but rather to lay out the issues and present a pilot study to test the methodology. This methodology should be refined, adapted, and applied more completely in a range of sites before conclusive statements can be made about the management of irrigation systems as multiple-use water resources.

Outline of the Paper

The following chapter gives a description of the irrigation infrastructure and the physical and socioeconomic characteristics of the study area. The information in this chapter is based on an earlier research done by IIMI as well as on the research done during this study. Chapter 3 describes the present water use pattern and quantifies the uses of different sectors by using a water accounting procedure. After the quantification of water use, chapter 4 deals with water quality issues and requirements for irrigation, drinking, and the environmental uses of water. Chapter 5 describes the institutional environment in the Kirindi Oya irrigation system, focusing on water-related institutions, land and water rights, and a variety of governmental and water user organizations. The description and analysis of the institutional framework go beyond the formal, state-defined rights and organizations, and also consider the customary rights and a variety of formal and informal user organizations. In chapter 6, the findings of a household water use survey are presented. A description is given of the different water sources used for various purposes, with an emphasis on the domestic uses of water. Also, an attempt is made to assess the importance of irrigation water and nonirrigation water sources for various household water uses by gender of the primary users. Chapter 7 discusses aspects of water pricing, economic value, and other values of water. The gross value and the net value added per m^3 of water for different productive uses are calculated using primary and secondary data. In chapter 8, complementarities, competition, and conflicts between different uses and users are examined. The major types of interactions between uses are also presented. The penultimate chapter describes the future directions for research in a planned follow-on study and the last chapter, chapter 10, gives the conclusions and implications for water policy and water management when multiple uses of water are recognized.

2. Description of the Study Area

Location and Physical Characteristics

The Kirindi Oya Irrigation and Settlement Project (KOISP) is located in the southeastern dry zone of Sri Lanka, about 260 km from Colombo (figure 1) and is the largest irrigation and settlement scheme in the south of Sri Lanka. The Kirindi Oya river is 118 km long and is fed by a catchment area of 1,203 km^2. The irrigation system is an expansion of the old Ellagala system, which comprised 5 ancient tanks. In the 1970s, plans were formulated to rehabilitate and augment the old Ellagala system. The implementation started in 1979, and in 1987, the first water supply was issued from the newly built Lunuganwehera reservoir through the new Left Bank (LB) and the Right Bank (RB) canals. The study area is an important tourist destination with the Bundala National Park situated downstream of the KOISP and the Yala National Park further away. Also, many pilgrims visit the area on the way to the shrines in Kataragama.

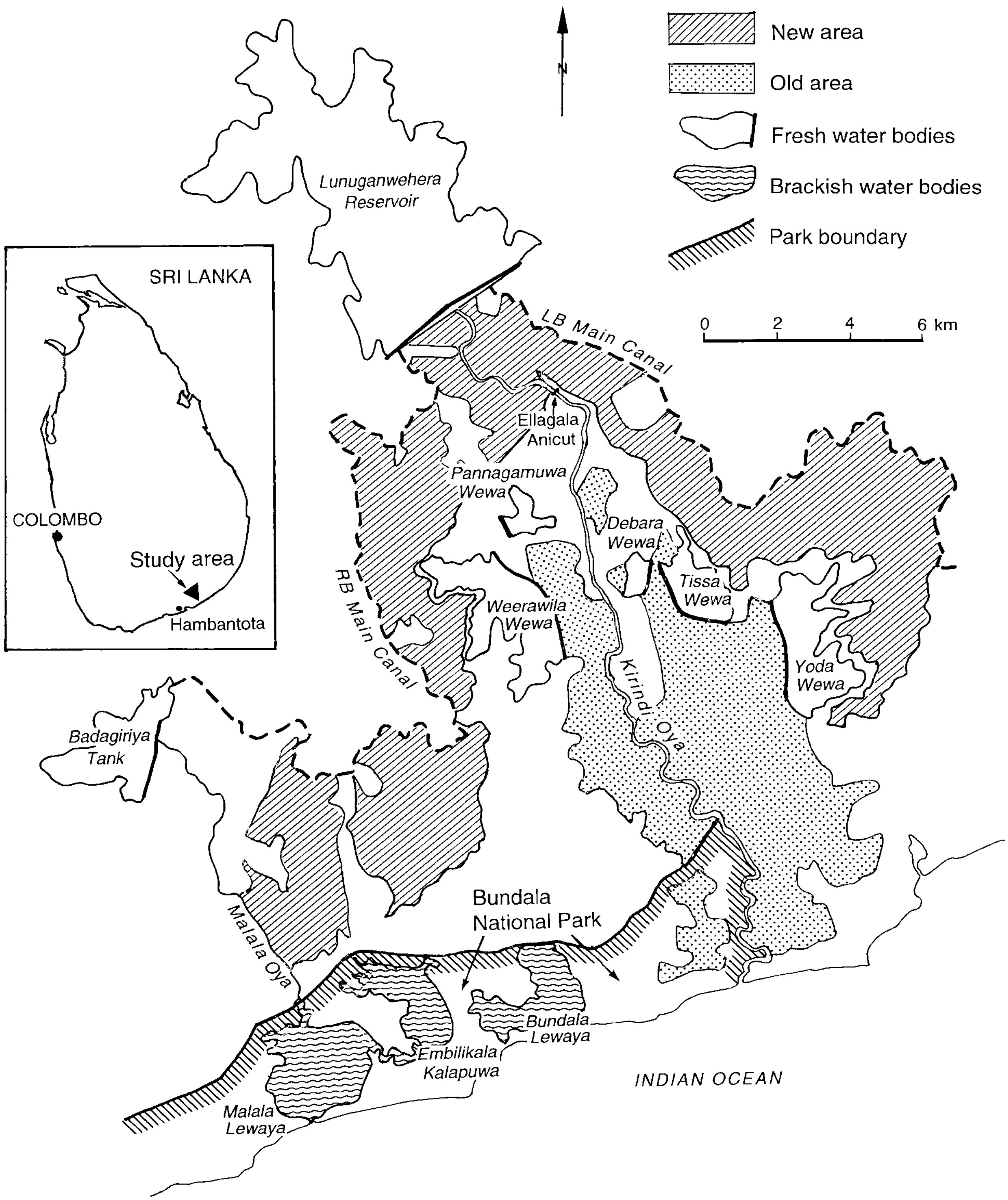
The study area falls within the low-country dry zone and is situated within 125 meters elevation above sea level (Cooray 1984). It lies within the broad, shallow valley of the Kirindi Oya, with the old Ellagala irrigation system falling almost entirely within the slightly uplifted flat alluvial plain. The newly developed areas of the irrigation system are situated around the old areas and have slopes of about 2–6 percent. The various sub-catchment valleys slope into the river and the tanks. The alluvial plain has an incised river, the Kirindi Oya cutting through it, and as a result, little or no river erosion hazards are encountered. The soils in the new area are more suited for non-paddy crops while soils in the old area are equally suited for paddy and for other crops.

The climate of the area is tropical and is characterized by nearly constant year-round temperatures (26–28 ^{o}C). Evaporation is uniform throughout the year, with an annual average approximating 2,000 mm. Mean annual rainfall is 1,000 mm with the *maha* (wet) season rainfall (October-March) approximately three times that of the *yala* (dry) season (April-September) (IIMI 1995a).

Socioeconomic Characteristics

The population of the old area, including the Badagiriya irrigation scheme is estimated as

FIGURE 1.
Map of the study area.



56,222 and that of the new area as 31,528 giving a total population of 87,750 for the entire study area. The ethno-religious make up of the population is predominantly Sinhalese (98%). The average household size estimated from field surveys is 4.8 persons per household in the old area and 5.1 persons in the new area.

The social composition of the population reflects the old system/new settlement phases of irrigation development in the area. Most residents in the old area are from families that have lived in the area for generations, as would be expected in an area with a thousand years of irrigation history. Therefore, 62 percent of the residents in the old area live in permanent houses compared with 15 percent of the residents in the new area. People in the old area have bigger houses, more consumer durables, and transport (bicycles, two- and four-wheeled vehicles) than those in the new settlement area. Furthermore, homesteads in the old area are well landscaped with vegetables, fruit trees, and other permanent vegetation (IIMI 1995a).

Residents in the new irrigated areas are settlers who acquired land either after being displaced from old holdings (alternate settlers, 55%), or under a government program to allocate new irrigated land to the landless from other parts of the country (open settlers, 45%). Many of the latter reported that political connections in their place of origin had helped them to acquire land. In addition to the 0.2 hectare highland, each settler was to be allocated 1 hectare of irrigated land (Stanbury 1989). The poorly developed physical and social infrastructure when the project began, combined with the need to develop their land and homestead sites, made life difficult for the settlers. For example, for several years, the only source of drinking water was bowser trucks that delivered water at points along the roadside. Further distress was caused by a lower water availability than was expected at the time of the project design. Many families were forced to migrate seasonally to cities or to their places of origin and diversify their sources of income, since livelihoods obtained from the irrigated production alone were insecure. Although it is not formally allowed, some settlers gave the opportunity to someone else to cultivate their land.

Under the irrigation development project, there has been a considerable government investment in the infrastructure and subsidies for housing. Literacy rates are high in both areas: 97.7 percent for men and 94.5 percent for women in the old area, and 96.7 percent for men and 93.4 percent for women in the new area. There has been a declining trend in dependence on agriculture and a rise in salaried employment (including 2% involved in foreign employment). Formal sector employment, especially in the government sector, is higher in the old area because of better transport facilities (IIMI 1995a). In 1994, average annual household income in the old area was Rs 66,800 and in the new area, Rs 36,072 (ibid).

Irrigation Infrastructure

The Lunuganwehera reservoir, the construction of which was completed in 1987, provides irrigation water to 5,400 hectares of the newly developed lands, about 4,200 hectares of the existing irrigated lands under the old Ellagala system, and to 850 hectares under the Badagiriya system. The tanks under the Ellagala system have been built over a thousand years ago. The old system was restored in 1877 by the construction of a new diversion structure (anicut) in the Kirindi Oya river at Ellagala. The Ellagala anicut diverts water to 5 ancient and previously independent tanks: Debara Wewa, Tissa Wewa, Weerawila Wewa, Pannegamuwa Wewa, and Yoda Wewa (see also figure 1).

The catchment area of the Lunuganwehera reservoir is 914 km². The reservoir has a gross storage capacity of 227 million m³ (MCM) and an active storage of 200 MCM. The RB main canal of the reservoir is 32 km long ending at the

Badagiriya tank, with a discharge capacity of 13 cumecs and a command area of 3,500 hectares. The LB main canal is 17 km long with a discharge capacity of 12 cumecs and a command area of 1,900 hectares.

The Lunuganwehera reservoir is built a short distance upstream of the Ellagala Anicut. A feeder canal from the LB main canal takes water to the Ellagala diversion. The newly developed areas surround the old irrigated area and drain into the old tanks. About 30 percent of the inflow into the old system is received directly from the Lunuganwehera reservoir and the rest from the rainfall runoff from the catchments of the old tanks and return flow from the water diverted to the new area.

The areas south of the LB drain into the old tanks: Debera Wewa, Tissa Wewa, and Yoda Wewa. Areas east of the RB canal drain into the Weerawila Wewa and Pannegamuwa Wewa and areas south of the RB canal drain into the Embilikala and Malala lagoons. These lagoons are part of the Bundala National Park. Embilikala is an inland lagoon with no direct outfall to the sea, while Malala has a direct outfall to the sea. An incised canal connects the two lagoons. Drainage water from old tanks in the upper reaches (Pannegamuwa Wewa, Debera Wewa, and Tissa Wewa) flows back to the old tanks in the lower reaches (Weerawila Wewa and Yoda Wewa) and to the Kirindi Oya river or to other outlets to the ocean.

The Badagiriya tank, which is built across the adjoining Malala Ara river basin has its own independent catchment of 350 km^2, and a storage capacity of 11.2 MCM, providing irrigation water to 850 hectares of land. The Badagiriya tank has been included in the study as it is augmented by the RB main canal of Lunuganwehera reservoir with a fixed volume of water annually. The augmentation had been necessitated because the water supply to the Badagiriya tank has been reduced considerably by the construction of many small tanks upstream. The drainage water of Badagiriya flows into the Malala lagoon.

3. Water Uses in the Kirindi Oya Subbasin

Methodology

Water users in the Kirindi Oya study area are all dependent on the same water from the network of reservoirs, canals, and rainfall in the catchment area. They are highly dependent on each other to obtain adequate water with good quality. The allocation rules, the means of distributing water, and the designs for improvement require a better understanding of the present water use pattern. To understand the water use pattern in Kirindi Oya, a water accounting procedure is used (Molden 1997). This procedure quantifies the different uses of water and gives a better understanding of the relative quantities used by different sectors. It also gives an indication of the performance of subbasin water management.

Water accounting classifies water balance components into uses by the different sectors. Water flowing into the subbasin from the Kirindi Oya river flows to the Lunuganwehera reservoir providing the main source of water in addition to rainfall. The water is put to a beneficial use—drinking water for people, crop consumptive use, and habitat for fish. As a result of the diversion to the use, the water either depletes from the subbasin, or returns to the subbasin, where there is a chance that it gets used again. There is considerable reuse of return flows in the area, especially within the irrigation sector. For example, return flows from the new area are readily recaptured by the tanks in the old areas and again diverted for agricultural use.

It is useful to study water at three levels: macro or subbasin, mezzo or service, and micro or use level. A macro point of view gives an understanding of the overall water resource availability. At a finer level of detail, studying irrigation services gives us an indication of how well water is being managed. When considering the use level, we get a better picture of how farmers irrigate fields, or how households use water.

Water Services and Uses

In the Kirindi Oya subbasin, two water services are distinguished: irrigation service and domestic service. The domestic service provides treated and piped drinking water to some of the inhabitants in the area. The irrigation service mainly intends to meet the needs of crops, but it also provides domestic water. The paths of water flow in the study area are shown in annex 1.

Irrigation Service

Irrigated field crop production

The sources of water for the irrigation service are the water releases from Lunuganwehera that, together with rainfall provides water for crop growth. Within the irrigation service area, two main interest groups can be distinguished: the new irrigated area, which can be further classified as the RB and the LB, and the old irrigated area. Most of the supply of the new area is served by the water remaining after supplying the old area. It is estimated that there are about 300–400 agro-wells in the area, providing supplementary water for cultivating other field crops (OFCs) and to a lesser extent, paddy.

Traditionally, rice is grown in the maha and the yala seasons if water is available. New improved varieties of rice are cultivated in majority of the area. The rice is broadcast. The most important OFCs cultivated in the system are chili, onion, green gram, cow pea, groundnut, and vegetables like brinjal, snakegourd, and tomato. Over the last few years, banana cultivation has been more popular with bananas planted in paddy fields and areas closer to canals or other water sources. The average area cultivated with paddy and OFCs and their yields are given in table 1.

TABLE 1.
Area cultivated with paddy and OFCs in the Kirindi Oya irrigation system (average from maha 1990 to yala 1997).

	Irrigable area	Maha (average)	Yala (average)
Area cultivated with paddy—old area (ha)	4,200	4,092	3,415
Area cultivated with paddy—new area (ha)	5,400	3,703	1,694
Total area cultivated with paddy (ha)	9,600	7,795	5,109
Paddy yield (mt/ha)	–	4.22	4.38
Area cultivated with OFCs (ha)	–	1,240	881
Total area cultivated in Kirindi Oya Scheme (ha)	9,600	9,035	5,990
Area cultivated in Badagiriya Scheme (ha)	850	665	333
Total area cultivated in KOISP and Badagiriya Scheme (ha)	10,450	9,700	6,323

Sources: Irrigation Department, Department of Agriculture, Irrigation Management Division and Agrarian Services Centers.

Domestic use

In dry periods when there is no cultivation, the ID issues water for 48 hours once in every two weeks to the LB and the RB to provide water for washing and bathing purposes. In 1995–1996, 1.4 MCM was supplied through canals for this purpose, while in the dry year (1996–1997), 11 MCM was supplied. A second source of water for domestic use, supplied indirectly by the irrigation service, is well water. Approximately, 2,800 homestead wells for domestic purposes are mainly located in the old area. These wells are recharged by water issued to the irrigated fields and rainfall.

Livestock

The main water sources for livestock to drink and bathe are small tanks that obtain their water from rainfall and the irrigation service. In the dry periods, these water sources dry up, and the animals are brought back to the KOISP area mainly to meet their requirements of water from the major tanks in the area and for grazing on paddy stubble. Currently, it is estimated that there are over 50,000 cattle and buffaloes, 3,000 goats, and 5,000 poultry in the area. Average milk yields are low, between 1-2 liters/day/animal. The highest yields are obtained during the wet months when food and fodder are available. There are no specific water sources or scheduled diversions for livestock.

As a consequence of the milk-based curd industry, there are also a lot of small curd pot making enterprises. Mud from the tank beds is used to make these pots used for holding curd. Bricks are also made from tank bed mud.

Fisheries

Inland fishing is undertaken in almost all the major tanks and in the Lunuganwehera reservoir. Depending on the availability, fingerlings are introduced once a year or once a season. Fingerlings are produced in the fish farms of the Department of Fisheries or the NGOs. Fish catch is high when the water levels in the tanks go down during the dry months (April–September) when fish get concentrated in the shallow water and are easier to catch. There are no scheduled water diversions for fisheries. Only the dead storage or the balance remaining after the irrigation requirements are met can be used as habitat for fish.

Forest, scrubs and grasses, and chena

Within the study area, there is a significant area covered with natural vegetation, homesteads, and *chena* (slash and burn) cultivation. These land use types benefit from the increase of soil moisture and groundwater levels due to percolation and seepage from paddy fields and canals. Much of this use can be considered beneficial, because the people use the wood as fuel for cooking, the forest conserves the land, and the grasses and scrubs are used for grazing of cattle.

Domestic Service

In 1997, about 95 percent of the population of the new area and 48 percent of the population in the old area had access to piped water (household survey 1997). This water is treated and comes from different sources as shown in table 2. In 1996, about 1 MCM of piped water was supplied.

Domestic and stand post connections use about 75 percent of the total supply. The construction and industry sector consumes 0.1 percent, tourist hotels 0.05 percent, the commercial sector 4.6 percent, religious institutions 3.2 percent, and the government institutions including schools and hospitals 17 percent.

The National Water Supply and Drainage Board (NWS&DB) estimated the total annual demand for domestic water at 1.7 MCM. The domestic water service provides about 1 MCM of the demand. The remaining 0.7 MCM is met by the irrigation service either directly when canal water is issued, or indirectly when it is pumped

TABLE 2.
Piped water supply schemes in the study area.

Scheme	Source	Supply area	Treatment	Amount supplied in 1996 (x1000 m^3/ year)
Lunuganwehera	Lunuganwehera reservoir	New area, Badagiriya scheme	Erosion + sand filtration + chlorination	570*
Tissamaharama/ Debera Wewa	Kirindi Oya	Tissamaharama/ Debera towns	Chlorination	247
Kirinda	Groundwater	Kirinda area	Chlorination	154
Total				971

*Not all of this goes to the piped water supply system. Project bowsers supply 19 percent of the people in the new area. This water comes from the Lunuganwehera drinking water supply scheme.

Source: (National Water Supply and Drainage Board).

from wells. Especially people in the old area rely more on wells for their domestic water uses. About 50 percent of the population in the old area use well water as their main source of drinking water compared to 5 percent of the population in the new area (household survey 1997).

Chena Cultivation

Within the subbasin, the practice of chena or shifting cultivation exists on 3,700 hectares. Chena cultivation relies almost entirely on rain, and does not benefit from the irrigation or the domestic services.

Environmental Uses

The wetland system of the Bundala National Park receives drainage flows from the KOISP. Water outflow from tracts 5, 6, and 7 drains into the Bundala Park and may affect the ecosystem (see figure 1). A proper analysis of the situation would require further water accounting studies for the adjacent river basins. At this moment there are no regulations about the amount of water to be drained into the Bundala National Park. The minimum or the maximum amount of water required to sustain the ecosystem of the park should be further studied to understand how much water should be committed to the area to sustain the park and how much of drainage outflow can be allowed.

Water Accounting

For water accounting, a water balance is constructed that considers inflows and outflows from an identified domain of interest, specifying spatial and temporal boundaries. For this study, the Lunuganwehera reservoir is the Northern boundary (the reservoir itself is not included in the study) and the other boundaries coincide with the Kirindi Oya river basin boundaries. Some definitions required for the analysis are given in box 1.

The accounting categories are derived from a water balance for the study period. Any change in the groundwater or the surface water storage is equal to the volume of rainfall plus Lunuganwehera reservoir releases minus the sum of evaporation and surface water outflows. As is commonly the case, this amount of data was not available, and estimates had to be made. The change in storage over a one-year time period was assumed to be negligible. Rainfall and reservoir releases were measured.

BOX 1.
Water accounting categories.

Water depletion is the use or removal of water from a water basin that renders it unavailable for further use. Two types of depletion are used:

- *Process depletion (PD)*: The amount of water diverted and depleted by a service to produce an intended good. Examples of process depletion are evapotranspiration of crops with water delivered by the irrigation service, and depletion of domestic water provided by the domestic service.

- *Non-process depletion (NPD)*: Water is depleted, but not by the process it was intended for. This can be further classified as beneficial non-process depletion or non-beneficial non-process depletion. Examples of non-process depletion are evaporation from trees and shrubs, evaporation from fallow lands, and evaporation of water that was delivered by irrigation services for domestic uses.

Committed water (C): That part of the inflow that is committed to other uses. An example is water committed to other users outside the river basin, or water committed to downstream environmental uses such as lagoons.

Uncommitted outflow (UC): Water that is neither depleted nor committed, and thus available for use within a basin or for export to other basins, but flows out due to lack of storage or operational measures. The uncommitted outflow at the subbasin level is the water that flows out of the Kirindi Oya into the ocean.

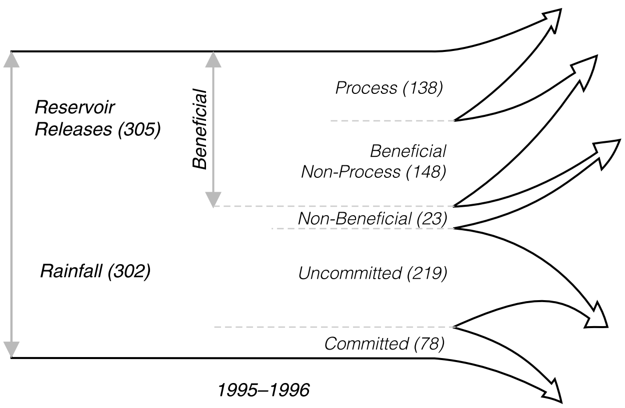
Nondepletive use (ND): A use of water that does not cause any depletion. Fisheries is a nondepletive use of water unless the reservoirs or channels are kept at a minimum level to keep the fish alive.

Water is evaporated from crops, trees and shrubs, bare soils, and free water surfaces. Standard methods (FAO 1992) were used to obtain crop evapotranspiration. Evaporation of bare soils beyond the amount included in evapotranspiration was assumed negligible. Free water surface evaporation was estimated by pan measurements.

This leaves two major unknowns; evaporation from trees and drainage outflows. As a rough estimation, a study from Huruluwewa, also in the dry zone of Sri Lanka (Munasinghe and Somasiri 1992) was used as an estimate of evaporation from trees and shrubs. The estimates of evaporation from trees, shrubs, and homesteads in the dry year were reduced from the wet year by taking into consideration the amount of rainfall available (Sakthivadivel, Molden, and De Fraiture, forthcoming). Finally, drainage outflows were estimated by closing the water balance. It should be recognized that there is a potentially large source of error in the estimation of evaporation from trees and shrubs, and thus there is a large degree of uncertainty around the drainage outflow estimation. Measurements of drainage outflow started in October 1997 and will be available in the future.

The water balance is made for 12 months, starting in the yala season (April) and ending at the end of the maha season (March). The years of 1995–1996 and 1996–1997 were considered in this study. Average rainfall in 1995–1996 was 1,142 mm and in 1996–1997, only 709 mm (average rainfall over the last 50 years was 1,025 mm). In 1995–1996, the total inflow from rain and the reservoir releases was 607 MCM (figure 2). Process consumption by irrigated crops was 98 MCM and for domestic and industrial uses 2 MCM (table 3). Beneficial non-process depletion includes evaporation from

FIGURE 2.
Water accounting for Kirindi Oya subbasin, 1995–1996 and 1996–1997.



trees, shrubs, and homesteads (149 MCM), and domestic consumption from well water (1 MCM). Well water is considered a non-process use of the irrigation service because the water was unintentionally derived from the irrigation system. Non-beneficial, non-process depletion is ET from fallow land and water surface (23 MCM). The outflow to RB tracts 5, 6, and 7 and the Badagiriya tank is considered as committed water (78 MCM). Finally, the outflow of water to the ocean, which during this year was estimated at 219 MCM is considered as uncommitted water and thus available for a use within the basin or for export to other basins.

For 1995–1996, the depleted fraction (DF), i.e., the amount depleted divided by the total inflow, was 0.51. This indicates that 51 percent of the water entering the area is depleted. The process fraction of depleted water, defined as the process depletion divided by total depletion, is 0.45. This indicates that only 45 percent of the amount of water that was depleted went to intended processes and this shows scope for considerable water savings. Most of these savings could be obtained by decreasing drainage outflow to the ocean.

A water accounting classification and quantification for the Kirindi Oya subbasin is shown in table 3. Each water use is classified as process depletion, beneficial non-process depletion and non-beneficial non-process depletion, non-depletive uses, committed, or uncommitted water.

Discussion

The results of the water balance should only be considered as an indication of the order of magnitude of the different water accounting processes in the Kirindi Oya subbasin as many water balance data are based on rough estimates or assumptions. In particular, data are missing for drainage outflow, ET from the forest, and scrubs and chena, and could only be roughly approximated. However, often first order estimates provide the basis for more in-depth analysis that provides important clues on increasing water productivity (Molden 1997). At the end of 1997, IIMI started measuring drainage outflows and at this moment a study is going on to calculate the ET of different types of land use

TABLE 3.
Classification and quantification of the water uses served by the irrigation and domestic service in the Kirindi Oya subbasin in MCM for 1995–1996 and 1996–1997.

Year		1995–1996	1996–1997
Unit		MCM	MCM
Inflow	Precipitation	302	188
	Reservoir water issues	305	168
	Gross inflow	607	356
Process depletion			
Irrigation service	ET paddy (irrigated)	96	45
Irrigation service	ET OFC (irrigated)	2	7
Irrigation service	Domestic use (canal water)	1	1
Domestic service	Domestic use (piped water)	1	1
Rainfall	ET chena	38	24
	Total	138	78
Beneficial non-process depletion			
Met indirectly through irrigation service and rainfall	Domestic use (wells)	1	1
	ET forest	28	19
	ET scrub/grassland	96	60
	ET homestead	24	15
	Total	149	95
Non-beneficial, non- process depletion	ET fallow land	4	9
	ET water surface	19	12
	Total	23	21
Non-depletive uses	Livestock		
	Fishing		
Committed	Badagiriya tank	1	1
	RB tracts 5,6, and 7	77	35
	Total	78	36
Uncommitted	Drainage outflow	219	126

in the area using remotely sensed imagery. In the future, the water balance can be updated and adjusted with more accurate data.

It is important to notice the order of magnitude of the drainage outflow. The Kirindi Oya system is known as a water-short system, but in a relatively wet year like 1995–1996, a lot of water is flowing to the ocean without being reused. In contrast, 1996–1997 was a relatively dry year. There was no cultivation during the yala season and only little cultivation during the maha season in the new area. During this dry year, it appeared that only a small amount of water was drained. The variability of water supply should be a consideration in the management of the area.

By far, the major user and consumer of water is irrigated agriculture. Except for a relatively dry year as 1996–1997, water diverted and depleted by domestic and industrial uses is very small in comparison to the quantities used by crops. Certain important uses such as fisheries and livestock deplete only a minimum amount of water, but add an important economic value. It would appear that at least on an annual basis, there is no shortage of water supplies, and hence there is a large scope to improve irrigation services to obtain more crop consumptive use.

4. Water Quality Issues

Although the quantity of water for domestic use is a small proportion of the total water depleted in an irrigated area, the quality requirements for domestic water use are considered to be higher than the irrigation water quality requirements. Satisfying the irrigation water quality requirements does not mean satisfying the domestic and the environmental water quality requirements. For example, nutrient-rich water benefits irrigated agriculture, but it is a concern for domestic use because of the possible negative health effects of high nitrogen, phosphorus, and bacterial content.

The availability and quality of shallow groundwater in Kirindi Oya is influenced by irrigation water supply. The groundwater is recharged with water from the fields, tanks, and canals as seepage water in addition to the direct percolation of precipitation. During this process, soil minerals and other chemicals get dissolved in the water. Many shallow wells are constructed adjacent to the field canals and rivers because water tables in those locations are expected to be high. The water table depth is often less than 1m, but fluctuates greatly depending on the time of the year.

In September 1997, the water quality of the Lunuganwehera reservoir, 6 major tanks, the Embilikala lagoon, 2 sites in the Kirindi Oya river, 2 main drainage canals, and 8 dug wells in the study area was measured for 10 selected parameters. The water quality analysis followed the sampling procedure and analysis methods recommended by the Laboratory Service of the NWS&DB. Table 4 shows the results of the measurements. Additionally, the electrical conductivity (EC) of 85 shallow wells was measured during late December 1997 to early January 1998 using a portable conductivity meter. The EC is commonly used to estimate the soluble salt content in solution, in this case water. The average EC of the wells was 2.1 milliSiemens per centimeter (mS/cm) with a standard deviation of 1.8 mS/cm.[1] Further, household interviews on water quality perceptions were carried out among the households using the 85 wells for domestic purposes. Of the 10 parameters in table 4, only the first four are discussed in the following sections.

Irrigation

During most of the year, evaporation is higher than precipitation, which may cause salinity problems if excess salts are not leached out of the plant root zone. In fact, a salinity problem was reported in the RB command area after the construction of the Lunuganwehera reservoir, which resulted in a reduction of rice production (IIMI 1995a). A salinity-affected area of approximately 200 hectares is also recorded in the lower parts of the command area, caused by improper drainage, which resulted in the accumulation of salts.

The quality of water in the reservoir, tanks, and the main canals when used for irrigation purposes falls into the Class 2 category (tables 4 and 5). This means that there is a moderate salinity hazard and the water can be used for irrigation with moderate leaching for most crops. The lowest EC value 0.33 mS/cm was observed in the Lunuganwehera reservoir. The EC of the downstream tanks was higher than that in the upstream tanks, indicating an entry of elements along the watercourses.

Domestic Use

Besides the water quality measurements for irrigation, table 4 also shows the drinking water

[1]Minimum EC measured was 0.2 mS/cm and the maximum, 10.4 mS/cm; skewness of the measurements was 2.4 mS/cm, and the median was 1.5 mS/cm.

quality standards for Sri Lanka. For all sources, color exceeded the maximum desired levels, especially for surface water. Color is known to be an important criterion on which people base the choice of their drinking water source (WHO 1984).

The shallow ground water, Kirindi Oya river, and drainage water had high levels of hardness and alkalinity. Like the Kirindi Oya river, drainage water exceeded the maximum desirable levels of alkalinity and hardness (see table 4). The high level of hardness can result in scale deposition, particularly when heating the water, and can lead to an increased incidence of urolithiasis (kidney stones) (WHO 1984 and 1993). It was reported that the people have sticky hair when well water is used for bathing. Prevalence of urolithiasis in goats in the area has been reported.

Water is not suitable for drinking when it has total dissolved solids (TDS) of more than 1,000 mg/l (WHO 1993). A TDS below 600 mg/l is considered to be good drinking water while water becomes increasingly unpalatable when the concentration is greater than 1,200 mg/l. Based on the EC measurements in table 4, TDS can be calculated applying the formula:

TDS (mg/l) = 640 x EC (mS/cm) (Tanji 1996). This results in a TDS of 1,459 mg/l for shallow wells, 448 mg/l for irrigation water, and 570 mg/l for Kirindi Oya water. Therefore, as far as TDS is concerned, well water is unsuitable for drinking, while the irrigation water and river water are suitable. The EC measurements and household interviews showed that 22 percent of the 85 shallow wells were not preferred for drinking, and 40 percent of the wells used for drinking had a saline taste.

Even though the results of the measurements indicate that surface water is better for drinking than groundwater in terms of chemical quality, surface water is more likely to be contaminated with fecal material. There is a concern of increasing public health risks due to the usage of untreated tank water (CEA 1994). People use the tanks and canals for bathing and washing clothes, while livestock also use them for drinking and bathing.

TABLE 4.
Water quality measurements and standards in the Kirindi Oya System (September 1997).

		Water quality in the Kirindi Oya system					Drinking water quality standards of Sri Lanka	
Measurement	Units	Irrigation water	Kirindi Oya water	Drainage	Shallow well	Embilikala lagoon	Maximum desirable level	Maximum permissible level
Electrical Conductivity	mS/cm	0.70	0.89	1.67	2.28	1.80	0.75	3.5
Color	TCU*	7.7	7.5	7.6	7.5	8.0	5	30
Alkalinity (as $CaCo_3$)	mg/l	211.3	338.0	265.0	497.1	190.0	200	400
Hardness (as $CaCo_3$)	mg/l	192.3	240.0	400.0	650.3	450.0	250	600
Temperature	C	29.6	30.0	33.1	29.0	33.0	–	–
Nitrate (as N)	mg/l	0.56	0.70	0.75	0.43	0.50	–	10
Nitrite (as N)	mg/l	0.13	0.01	0.12	0.01	0.06	–	0.1
Phosphate (as PO_4)	mg/l	0.18	0.23	0.15	0.38	0.17	–	2.0
Sulphate (as SO_4)	mg/l	36.3	50.0	45.0	72.1	NA	200	400
Chloride (as Cl)	mg/l	93.5	78.0	320.0	416.9	380.0	200	1200

*True Color Units (WHO 1984).

TABLE 5.
Classification of irrigation water salinity.

Class	EC (mS/cm)	TDS in PPM	Characteristics
C1	0.1–0.25	60–160	*Low* salinity hazard; water can be used for most crops on most soils.
C2	0.25–0.75	160–480	*Moderate* salinity hazard; water can be used with moderate leaching for most crops.
C3	0.75–2.25	480–1,440	*Medium-high* salinity hazard; water for use on soils with moderate good salt tolerance, leaching is required.
C4	2.25–4.00	1,440–2,560	*High* salinity hazard; water for use on well-permeable soils with salt tolerant crops; special leaching requirements must be met.
C5	4.00–6.00	2,560–3,840	*Very high* salinity hazard; water generally undesirable for irrigation; to be used only on highly permeable soils with frequent leaching and with highly soil-tolerant crops.
C6	Above 6	Above 3,840	*Excessive* salinity hazard; water unsuitable for irrigation unless under very special conditions.

Source: International Land Development Consultants (ILACO) 1981.

Environment

The Kirindi Oya irrigation system includes the Weerawila-Tissa Wildlife Sanctuary which contains 4 tanks with a total surface area of 1,590 hectares. The tanks are defined as wetland and recognized as a refuge for ducks and waterbirds. The CEA (1994) reported possible effects of changes in water levels in the tanks and water quality on the ecology and wildlife of the sanctuary as follows:

- Negative impact on fish population and diversity caused by reduced water levels, especially in the yala season.
- Negative impact of extreme water levels on resident and migratory birds, when tanks are dry or when the water level is too high for waders, dabbling birds, etc.
- Risk of eutrophication of tanks resulting from dung and urine from livestock, discharge of domestic effluents, and fertilizer runoff.

There is no doubt that the quantity and quality of water in the sanctuary are greatly influenced by irrigation and human activities within the Kirindi Oya scheme as the hydrology of the sanctuary is directly related to the irrigation management. The tanks receive water through the LB main canal of the Lunuganwehera reservoir, in addition to the drainage water from the RB tracts.

The Bundala National Park is located downstream of the Kirindi Oya scheme. It covers 6,216 hectares and encloses 5 brackish lagoons of 2,250 hectares (CEA 1993). The drainage water from the RB tracts 5, 6, and 7 and the Badagiriya Irrigation Scheme flows into Embilikala and Malala lagoons, respectively. Over the past years, it has become clear that the ecosystem of those two lagoons has been severely affected by the drainage water coming from the Kirindi Oya scheme. Natural fluctuations in salinity levels have disappeared and the two lagoons have become freshwater lakes. The change in salinity levels influences the population of water birds as it affects the quality and quantity of their food supply (CEA 1993). Prawn farming requires brackish water conditions and previously it sustained several hundred families, but it has now almost disappeared from the area. Eutrophication is also a problem in the lagoons. Water has a greenish color due to the accumulation of nutrients and increase in green algae. This might be caused by overgrazing with direct deposit of animal feces in surface water as well as high fertilizer runoff from the irrigated area. On the other hand, an increase of drainage flow may benefit the other wildlife and livestock in the national park as more fresh water becomes available.

5. The Institutional Environment

The Government of Sri Lanka claims legal ownership of all surface water and does not recognize any system of individual or group water rights. Water use rights are allocated to land in designated irrigated areas through a process of seasonal planning or allocation (Brewer, forthcoming). The Irrigation Ordinance defines mechanisms for seasonal water allocations but adds that all decisions are subject to review and change by the government. The final authority is the Minister in charge of irrigation (IIMI 1995b). The negotiation processes for water are influenced by the structure of the government and the user organizations. Even within the government, different agencies' regulations (or the interpretation of different officials within an agency) may vary. Another complication with the definition of water rights is the overlap of various hydrologic units and administrative boundaries (Hoogendam 1995).

There is no comprehensive water resources policy, but several institutions at different levels formulate water policies relating to their respective sectors (e.g., Irrigation Department and NWS&DB). Until April 1996, there was no institutional mechanism to coordinate the activities of these institutions, so that there were considerable duplications of efforts. In April 1996, the establishment of a Water Resources Council was officially approved. This council is coordinating the implementation of the action plan for comprehensive water resources management. The Water Resources Council is only an advisory body and is part of a temporary arrangement aimed at coordinating activities in the water sector, including the formulation of water resources policies and legislation.

Water Rights and Institutions in Kirindi Oya

The KOISP falls within the Southern Province, but the main reservoir and the catchment area are within the Uva Province. Therefore, the Central Government has legislative and executive powers over the entire system. The Kirindi Oya river basin falls within 3 districts and 7 divisions while the KOISP falls within 2 districts and 4 divisions. In addition to these administrative jurisdictions, there is a Project Management Committee (PMC) that coordinates the activities of various government agencies related to irrigated agriculture and makes decisions for seasonal water allocation.

Field Crop Production

Water rights tied to irrigated land constitute one of the most widely recognized forms of water rights in Sri Lanka, particularly in Kirindi Oya. Generally, farmers in the old area own their homesteads and irrigated land, while settlers in the new area have been allotted management and use rights[2] by the government. Alienation rights to land for settlers are limited: they cannot legally sell or lease it, and while it can be inherited by a successor nominated by the original allottee, the land cannot be subdivided between heirs (Stanbury 1989).

In developing the KOISP, the government recognized the seniority of the existing water rights of farmers in the old area. Those farmers were assured that their water use would not be reduced by the project, and in fact, they were able to increase their cropping intensity due to more reliable water supplies from the new reservoir.

[2]The following analysis of rights uses a hierarchy of bundles of rights identified by Schlager and Ostrom (1992) : access and withdrawal (use rights), management, exclusion, and alienation (control rights).

TABLE 6.
Water allocation pattern in the Kirindi Oya Irrigation System.

Area	Maha season (wet season)	Yala season (dry season)
Old area	Enough water to cultivate 100% command area with paddy.	Enough water to cultivate 70% command area with paddy.
New area	2/3 command area with paddy; others are encouraged to plant OFC. If there is sufficient rainfall they can cultivate a late paddy crop.	Areas that did not get water for paddy during Maha have priority.

Source: Brewer, forthcoming.

Based on this guarantee, the lands in the old area were given priority for water, even if it meant that the new area did not get any water. The general basis for water allocation to the old and the new areas is given in table 6.

Since 1978, various experiments giving greater responsibilities to farmers in irrigation management were carried out in Sri Lanka (Brewer 1994). Kirindi Oya was brought under the Integrated Management of Major Irrigation Systems (INMAS) program in 1986. In the KOISP, this program included the creation of 690 Field Channel Groups, 59 Distributary Channel Organizations (FCGs and DCOs), 4 Sub-Project Committees (SPCs), and 1 PMC. The Farmer Organizations (FOs) were created to assist the management of the irrigation system, while the Project Committees (SPCs and PMC) give farmers a voice in allocation decisions.

The PMC is the main organization involved in water allocation in Kirindi Oya. This is a joint government-user group entity composed of farmer representatives from various parts of the system along with representatives from a range of government agencies (e.g., Irrigation Department, Department of Agriculture, and Department of Agrarian Services). In addition to water allocation decisions for irrigation, the PMC attempts to resolve other problems brought to them, particularly problems that require the assistance of one of the government agencies.

The PMC allocates water for agricultural purposes by negotiated seasonal planning meetings. In developing the plans it is assisted by the SPCs for Ellagala, new area LB, new area RB, and Badagiriya. The seasonal planning is flexible in the sense that it adjusts water allocation to water availability. Until 1991, allocation decisions were made by the officials without direct input from the farmers. The seasonal decisions made by the PMC were more acceptable since the farmers had some input. The PMC authority was also accepted by the government officials because of the government's participatory management policy.

Water distribution—the delivery of water to execute the water allocation plan—is the responsibility of the ID at the reservoir and the main canal levels, and the responsibility of FOs below the distributary level. In addition to water distribution, the FOs are responsible for maintenance of the distributary and field channels. If they wish to, the FOs can take on other functions. Their performance in maintenance seems to be satisfactory and, clearly, they have helped improve water distribution, at least at the field channel level (IIMI 1995a). Above that level, most FOs are weak and do not play a significant role in system operation. The FOs in the new area are weak because many farmers do not reside the whole year round or lease their lands to others. Another problem in the new area is that one FO can include farmers from different hamlets. This social division hampers the functioning of the FOs (ibid).

As individual water users, farmers with land in irrigated areas have use and alienation rights to water on their fields. Through participation in the FOs and the PMC, farmers have also acquired some management rights. The strength of these rights depends on the degree of participation of the individual farmers in the FOs and on the strength of farmer representative's voices on the PMC. Nevertheless, farmers' interests in water for field (especially paddy) crop production are better represented than any other type of use in water allocation decisions.

Garden Crop Production

There is no recognized water right for homestead gardens. On the contrary, taking water from either the irrigation canals or the piped water supply for gardens is prohibited (NWS&DB 1997a). Taking groundwater from private wells, however, is not regulated and the development of agro-wells is even promoted by the Agricultural Development Authority. Informally, a certain amount of watering gardens from canals or domestic supply systems may be tolerated, and runoff or wastewater from domestic use is certainly applied to gardens. However, garden production is treated as an individual use, and there is no user group to represent these interests.

Livestock

Water is not especially issued for livestock uses like drinking and bathing. The water use rights of livestock are informal and not clearly defined. The fact that customary lands for cattle grazing and watering places were not recognized in the development of the Kirindi Oya system indicates the relatively weak water rights for livestock. This increased the contact between herds and fields, which causes crop damage and conflict between livestock and crop production. To solve this problem, three Cattle Owners' Farmer Organizations (COFOs) were formed in 1991.

These organizations are working together with the government agencies to find alternative grazing for the herds. The leaders try to work with the FO leaders to resolve disputes about crop damage. Even though livestock owners are represented on the PMC, their participation in that forum is primarily related to crop damage and does not involve water management decisions, and therefore they are not granted management rights.

Fisheries

There are a variety of government, NGO, and user organizations involved in fisheries, but there is no coherent policy towards water use for fishing. There are Fisheries Cooperative Societies (FCS) for each tank and reservoir, and tank fishing rights are legally restricted to these cooperatives (Steele, Konradsen, and Imbulana 1997). Government assistance to fishermen is channeled through the cooperatives, that are responsible for checking whether the fishermen stick to the rules (e.g., size of holes in the nets). Access rights to water and the right to withdraw fish are regulated through the FCSs to their members. Because fishermen do not have a voice on the PMC for regulating water levels, they do not have management rights over water. However, the fishermen do not seem to make an issue of this because most have agricultural land. They consider fishing as a secondary activity, a subsidiary use of water, while the first and most important activity is agriculture.

Domestic

Although the ID was nominally responsible for construction of the domestic water supply scheme, responsibilities were surrendered to the NWS&DB, and it continues to be responsible for the piped water supply system (IIMI 1995a). When there is no irrigation, the ID supplies water in the canals once in 14 days for domestic purposes.

A certain amount of the Lunuganwehera reservoir water is set aside for the NWS&DB to provide water for the piped water supply system. When the water is above the dead storage level, i.e., 45.5 meters above the mean sea level (MSL), the NWS&DB has a water right to extract 5,000m^3 of water per day. When the water level is at or below 47.5 meter above MSL, only the NWS&DB has the right to pump water from the Lunuganwehera reservoir. Further, a water right to abstract 600m^3 from two tube wells at Kirinda is granted to the NWS&DB to supply the old area. The NWS&DB also has a right to abstract water from Tissa Wewa to provide water for domestic purposes. During the 1992 yala season, water issues from the reservoir for irrigation were even stopped in early July to protect the domestic water supply (Brewer, forthcoming). This is an indication of the priority given to the domestic water supply. It is noteworthy that the NWS&DB is not represented on the PMC.

On the users' side, standpipe committees of approximately 15–20 households are established under the supervision of the NWS&DB to manage stand posts for piped water supply. These associations are informal, i.e., no authority is vested in them under the existing legislation, although they are responsible for collecting user charges from the households who make use of the standposts. User charge for one household is Rs 11 per month. It is also the responsibility of the members of the standpipe committee to safeguard the water stand, and the committee is liable for the misuse of water by the standpipe users. If the users do not stick to the rules and regulations set by the NWS&DB, the water is disconnected and a reconnection fee of Rs 250 has to be paid by the committee (NWS&DB 1997a). Although the NWS&DB does not allow for uses other uses than drinking (ibid), the water from standpipes serves a variety of uses e.g., bathing, laundering, and brick making. The users allow each other to use standpipe water for these kinds of purposes because there is no other water source nearby.

The formal rules grant members of the standpipe committees limited use rights, and rights (which they may or may not exercise) to exclude other users, or users who do not pay. However, the rules are specified by the NWS&DB, so that users have no formal management rights. Informally, however, each group decides what uses will be tolerated or even considered legitimate, so there are some de facto management rights. Those who draw their domestic supplies from sources other than the NWS&DB system have acknowledged rights to water through reservoir releases even when there is no irrigation. Beyond this, there is much less regulation of use.

Other

No special water rights and allocation are recorded for recreation, wildlife, and the environment. The Air Force has a water right of 2,000m^3 per month from the NWS&DB. As far as industrial water use is concerned, there is one garment factory in Kirindi Oya, which has a water right for 1,300m^3 per month from the NWS&DB. According to the ID, a number of hotels have requested water, but have been denied permission to take water from tanks and other surface sources. They therefore turn to groundwater abstraction, which is regulated less (although the ID notes that this water ultimately comes from the irrigation system). Hotels have also turned to groundwater because the NWS&DB charges for hotels (Rs 27 /m^3) have tripled since 1984, and are considerably above the charges for household use, schools, and religious institutions (NWS&DB 1997b). Water is not allocated to small-scale enterprises like curd pot making and brick making. People make use of the available water, which has been allocated for other purposes like irrigation and drinking. No user groups were encountered representing the water interests of industrial or micro-enterprise water users.

Institutional Structure for Multiple Water Use

Many of the use and management rights of different categories of water users are negotiated and mediated by a range of formal and informal organizations. Table 7 gives an overview of the range of organizations found in Kirindi Oya that relate to a type of water use.

In many cases, there are parallel government agencies and user groups for each type of water use. In some cases, there are even multiple government departments related to a type of water use. However, effective coordination among departments is very difficult. In Sri Lanka, government organizations are strongly hierarchical with clear lines of authority. Officers are generally not rewarded for the effort put to coordinate with other departments and are sometimes punished for it (IIMI 1995a).

We were not able to identify any user group representing homestead gardens, perhaps reflecting the autonomous (and sometimes even atomized) production. While wildlife does not have a user organization, the interests of wildlife are represented, to some extent, by the environmental NGOs, both national and international. However, these do not make their presence felt at the local level. There is a district-level Bundala Wetland Management Committee (BWMC) that includes representatives from government agencies (e.g., Department of Wildlife Conservation, Irrigation Department) as well as from user groups (e.g., salt farm). Although user groups' representatives are included on this committee, it does not provide a forum to deal with problems related to multiple uses of water because it is not on the irrigation system level. There is no linkage between the BWMC and the PMC, nor is the Department of Wild Life Conservation represented on the PMC.

The negotiations over water allocation between different uses take place not only among user groups, or between user groups and the

TABLE 7.
Government agencies and user groups representing different types of water uses.

Type of water use	Government agency	User group
Field crops	Irrigation Department* Irrigation Management Division* Land Commissioner Department* Agrarian Services Department* Department of Agriculture* Divisional Secretaries*	Farmer Organizations* (distributary as well as field-channel level)
Garden crops	Agricultural Development Authority	Not represented
Fisheries	Aquaculture Development Division of the Ministry of Fisheries	Fisheries Cooperative Societies
Livestock	National Livestock Development Board Department of Animal Production and Health	Cattle Owners' Farmer Organizations*
Domestic	National Water Supply and Drainage Board Local Government Authorities	Local standpipe committees
Industry/ small-scale enterprises	National Water Supply and Drainage Board Local Government Authorities	Not represented
Wildlife/ environment	Department of Wild Life Conservation Central Environmental Authority	National/International NGOs

* Represented on the Project Management Committee.

government, but also among government agencies. Of these, the ID is seen as the strongest, with the greatest control over water releases. For example, the Department of Wildlife Conservation has requested changes in water flowing to the Bundala sanctuary to preserve the salinity balance in the wetlands, but it does not feel it can direct the ID. The ID feels it is responsive in allocating domestic water from the reservoir, but the NWS&DB does not always think this is the case.

Traditionally, water allocation has been carried out by the ID under the Irrigation Ordinance. The recent development with many subsectors competing for water stresses the need to create a new institutional setup to handle water sector coordination problems (Rasmussen 1994). This kind of organizational framework that encompasses all water uses and users is lacking, even within the government. The PMC and its seasonal planning meetings before every season provides a first step in this direction, by including various government departments as well as farmer representatives from each command area. To resolve disputes due to damage of crops by cattle, representatives of COFOs also attend these meetings. Domestic water allocation issues can also be raised and considered at these meetings, but they do not cover other types of water use. Seasonal planning meetings might give scope for dealing with other types of water uses and issues when representatives of relevant user groups and agencies can participate. For this to be effective, representatives of different user groups must not only be included on the PMC, but also have a strong enough voice to raise their own water-related issues. Further coordination, between government agencies and user representatives is needed if the Kirindi Oya system is to accommodate the needs of all water users, and deal with the potential complementarities as well as trade-offs involved in multiple water use.

6. Household Uses of Water

The information presented in this chapter relates to the findings from the household water use survey among 156 families in the study area. The objective of this household survey was to identify the variety of agricultural and nonagricultural uses of irrigation water. At the same time, an attempt was made to assess the importance of irrigation water when compared with nonirrigation sources.

Methodology

The surveyed households were located in 10 clusters with 5 each in the new and the old areas of the Kirindi Oya system. The households were selected at random from the total number in the clusters from the old and the new areas at a fixed percentage of 0.70 and 1.30, respectively. The random selection was based on the “voter’s list” generated for the local elections in Sri Lanka in 1996. The information collected is believed to be representative of the whole Kirindi Oya system but the data presented below do not consider seasonal differences. The survey was carried out over a 7-month period from May to November 1997. Quantitative information collected through a questionnaire presented to each household was supplemented with qualitative information collected from repeated visits to the same households and via informal or formal group discussions in the 10 selected clusters. With regard to questions relating to the water used in agriculture, the information collected represents the last season when the fields were cultivated. The qualitative information was collected to provide more in-depth information to explain why a certain source was used and who was the person responsible within the household for providing labor in relation to a certain water use activity. In the description given below, the different water sources used by the households for various purposes are given with an emphasis on the domestic uses of water.

Household Uses of Water by Sector

Irrigation water is defined as water from tanks and irrigation or drainage canals. Nonirrigation water comes from the piped water supply system, homestead wells, the Kirindi Oya River, or rainfall. It should, of course be acknowledged as mentioned before, that a large proportion of the groundwater used from the homestead wells is in fact, seepage from the irrigated areas. Also, part of the piped water system has its origin at the Lunuganwehera reservoir. However, the water no longer flows via irrigation structures and is in one way or other treated and possibly pumped.

The first priority water source for a range of activities is given in table 8. Rice cultivation obtains water exclusively through the irrigation canal system and all inland fisheries take place in the reservoir and irrigation tanks. The small number of families involved in home industries is almost equally divided as families dependent on irrigation and nonirrigation sources. Of the most important income-generating activities for the households, only raising livestock and shifting cultivation are dependent on nonirrigation sources to any significant extent, mainly rainfall. Close to half the households prefer or are dependent on irrigation water as a source for laundering, bathing, or recreational uses. But hardly any household makes use of irrigation water for drinking and cooking.

Water-Related Labor Input for Fisheries, Agriculture, and Livestock

In the vast majority of households, a male was the main person responsible for water-related activities in rice farming (86%). In the remaining households it was a shared activity between men and women. For overall labor input into rice production, the male members were principally responsible in 67 percent of the households, with the responsibility being shared in the remaining households. In homegarden production, a female

TABLE 8.
The importance of irrigation water as first priority water source in comparison to other sources of water for a variety of uses.

Uses	Number of respondents	Use of different sources (%)	
		Nonirrigation water	Irrigation water
Irrigated agriculture			
Rice	93	0	100
Other field crops (e.g., onion)	17	0	100
Shifting cultivation	30	100*	0
Homegarden	54	87*	13
Cattle, buffaloes, and goat	20	45	55
Inland fisheries	9	0	100
Domestic			
Laundering, bathing, and recreational	156	96	4
Drinking, cooking, sanitation, and washing utensils	156	53	47
Home industries	17	41	59

*Including water from rainfall.

member of the household was the main person responsible for providing irrigation water in 52 percent of the households and it was in only 37 percent that a male member was the main person responsible. However, as indicated in table 8, most of the homegarden production was dependent on rainfall and the additional water from irrigation was limited. In 44 percent of the households, the women provided most of the overall labor into homegarden cultivation while only 32 percent of the males provided most of the labor, with the responsibilities being shared in the rest of the households. Precipitation was the only source of water for shifting cultivation and therefore, there is no gender differentiation in water-related labor input. In shifting cultivation, the work is shared almost equally among the household members but some gender differences are associated with the different tasks. The type of inland fisheries practiced depended on the availability of water in the irrigation tanks and the households provided no water management or water-related labor input. In the case of home industries, the types of production were so diverse that no general conclusions could be drawn.

Domestic Uses of Water

A very heavy burden was placed on the households, where the source of domestic water was distant from the homestead. Clearly, a reliable water supply close to the settlement is a very high priority for the community. In some of the households, the time spent fetching domestic water could amount to ‘several’ hours a day and an individual from the household sometimes had to go to the standpipe as early as 4 or 5 o’clock in the morning to wait in a queue for water. At times of the year when the homestead well runs dry and water is not available, more time is spent fetching water in the irrigation canals. Fetching water for domestic use was mainly done by women or children (male and female). However, where the household is dependent on a water source some distance away from the house, the males were often involved in fetching water in large buckets that they transport on bicycles or tractors. Only two households included in the study mentioned that they purchased water from water vendors.

Drinking and Cooking

Respondents stated that they obtained water for drinking and cooking from either a tap (70%) or a well (30%) because these sources were perceived as clean. Convenience was another important factor as the taps and the wells were generally located close to the homes. Some people preferred using well water because, unlike piped water, there was no fee for its use. Some families, especially those living close to the sea, preferred tap water because the groundwater is saline. Water for cooking was mainly used by females of the household (69%). Virtually all members of the household were involved in fetching water. But in 44 percent of the households, women provided most of the labor to fetch water for drinking and cooking, whereas, men were mainly responsible for this task in only 18 percent of the households. Only a few families mentioned that they boiled water before drinking, often only for children and sick people.

Washing of Utensils

The tap was the preferred source of water for washing of utensils, (64%) followed by well water (30%), and the canal (3%). As in the case of water for cooking and drinking, these were the preferred sources for reasons of hygiene and convenience. Easy accessibility was given as an important reason for the use of well water (45%) and tap water (30%). For about 20 percent of the households, the tap was the only source available to wash utensils. Women were primarily responsible for washing utensils in 70 percent of households and in the rest, the task was performed by children, men, and in some cases, by "all members" of the household.

Laundering

Canal water was used by 38 percent of the households for laundering, followed by tap water (30%), wells (15%), tanks (10%), and the river (7%). Fifty-seven percent of the respondents claimed they used canal water for laundering at one time or another (as compared to the 38% who used it as their main source). The free availability of canal water appeared to be the main consideration in the preference displayed in its use (60% of respondents). It also appeared to be the reason for the use of tanks (32%) and the river (33%) for laundering. Convenience was also a factor, as indicated by one-fourth of the respondents who used the river and those who used canals (22%), and tanks (19%). Respondents stated that these sources were "easy to use" probably because there were no waiting times, nor did users have to fetch the water in a bucket, and the availability of large amounts of water made washing easier.

Thirty-one percent of those using tap water for laundering said it was either because no other source was available or "it is easy to use" (25%) (convenience), and finally, because it was clean (16%). Similar reasons were cited for the use of well water.

In 65 percent of the households all members of the household claimed they participated in washing clothes and fetching water. It was not clear from the survey as to who was primarily responsible for laundering, but the qualitative data indicated that the senior woman in the household has much of the responsibility for this chore.

Bathing and Recreational Use of Water

The main sources of water used by the households for bathing (personal hygiene) and recreational purposes were the canals (35%), taps (31%), wells (14%), and the river (8%). Fifty-six percent of respondents claimed they used canal water for bathing and recreational purposes at some time and almost a fourth made use of the tanks at some point in time. In 80 percent of the households, all members were said to be involved in fetching water for this purpose. In approximately 10 percent of the households, a female was said to be the main provider of the labor input into these activities. The reason to prefer the canal as the main source of water for bathing and recreational use was because of the large amounts of water easily available at no cost ("ad lib use" 55%, "source is easy to use" 24%, and "close to household" 13%). From the qualitative information collected from the households, an additional reason for preference was given as "water quality." Canal water was perceived as of a quality ideal for bathing and recreation purposes. Similar reasons of cost and accessibility were cited as the reasons for tank water use although 13 percent of the respondents indicated that they used tanks because they were the only available sources. Tap water was used because it was the only source available (34%), "easy to use" (28%), and clean (19%); among its main users, well water was also regarded as "easy to use" (36%) and "a clean source" (27%). Convenience was cited as the most important determinant of the use of river water (77%), probably because these respondents lived close by the Kirindi Oya river.

Household Cleaning

The main source of water used to clean the house is tap water in 57 percent of the households and well water in 12 percent. Water from canals, tanks, and the river only plays a minor role for this activity, with around 3 percent of the households indicating one of these sources as the most important. The question of water being used for cleaning of the house was answered by 78 percent of the households and only 30 percent gave any additional information on labor input or reasons for preference. However, in the households that did respond, this activity seems to be mainly a female responsibility. Sixty percent of the responding households claimed that this activity is exclusively done by women followed by 26 percent of the households stating that this was an activity carried out by both the male head of the household and his spouse. Tap water and well water are used mainly because it is seen as a clean source and 'easy to use.'

Sanitation

Tap water was the main source for sanitary uses (59%); followed by the wells (28%) and canals, tanks, and the river (13%). The majority of the household members are involved in using and fetching water for sanitary purposes. Twenty percent of the households reported that the senior woman in the house was mainly responsible for this activity, probably because she, in addition to her own sanitation, takes care of the children's needs. Convenience was the main reason cited for the reliance on tap water and well water. Tap water and well water were not used out of quality considerations but mainly since this was the water that was brought to the house anyway.

Preferred Water Sources in the New and the Old Areas

The sources of water available to the households differed substantially between the old and the new areas. This affected the selection and prioritization of water sources for different purposes. In the old area, wells were more prevalent than taps, while the reverse was true for the new area. Also, in the old area, tanks and the river were an important source of water for some purposes. A Wilcoxon paired sign rank test was conducted for all sources and not just for the first priority source. Water sources, which contributed less than 5 percent of the total water used by the household, were eliminated. The results are summarized in table 9.

Interestingly, in the new area, tap water is the preferred source for all purposes. Wells are also used for all purposes and there is an equal preference between wells and canals for laundering, bathing, recreation, and sanitation. In the old area, the sources and preferences are more varied with wells being either preferred or equal to all other sources.

TABLE 9.
Results of ranking exercise for domestic water uses and sources.

Purpose	Order of ranking	
	Old area (n=82)	New area (n=74)
Drinking and cooking	Well = tap	Tap > well
Washing of utensils	Well > tap	Tap > well
Laundry	Well = canal > tap = tank	Tap > well = canal
Bathing and recreation	Well = canal > tap = tank	Tap > well = canal
Sanitation	Well > tap > canal = tank = river	Tap > well = canal

7. Valuing the Multiple Uses of Water

Irrigation water is used for many purposes other than irrigating field crops, as is shown in the previous chapters. The importance and value of multiple uses of irrigation water are often underestimated. According to Bhatia (1997), direct economic benefits to the farmer (from crop output) reflect only a small proportion of the total benefits to the community of using water in irrigated agriculture. An irrigation infrastructure provides nonirrigation benefits to other user sectors and ignoring these benefits will result in a serious underestimation of the benefits available from the volume of water that is diverted for irrigation. The valuing of water for multiple uses should ensure that the full range of values placed on water in competing uses is observed (Pigram 1997) and taken into account when water allocation decisions are being made.

The Value of Water

While talking about valuing the water, it is good to distinguish different concepts: water pricing, economic value of water, and other values of water.

Water Pricing

Water pricing (water use fee) is meant to collect money from the users in such a way that all or a portion of the construction, operation, and maintenance costs of the system are recovered. Hence, users pay a price to use a certain service, either the irrigation or the domestic service. There is, in fact, a considerable debate among professionals regarding the amount to charge for the use of irrigation. Further, in a multiple user context this leads to questions of who should pay for the water service: the irrigators, livestock owners, fishermen, domestic users, or brick makers? Even when an irrigation system is considered as a single purpose unit, it is questionable who should pay for the water. The general consensus is that farmers should pay the operation and maintenance (O&M) costs. However, the construction of government irrigation schemes and expansion of irrigation has resulted in lower cereal grain prices. Consumers have been the major beneficiaries. Thus it seems unreasonable to charge farmers the cost for construction or rehabilitation.

In Sri Lanka, farmers enjoy irrigation facilities that are provided by the government free of charge. The government has invested money in construction and maintenance of the irrigation schemes and it offered free O&M of the schemes in addition to free land to settlers (Upasena and Abeygunawardena 1993). In 1984, the government imposed an irrigation fee in major irrigation schemes. At first, farmers were to be charged half of the O&M cost (then estimated Rs 495 per hectare) but the charge would eventually rise to the full cost (Brewer 1994). In 1988, the fee collection scheme collapsed. In turn, full responsibility for resource mobilization and the O&M of the field and distributary channels of the major irrigation systems was turned over to the FOs.

The NWS&DB which supplies part of the domestic water in Kirindi Oya, makes use of quantity-based prices which vary according to the user. For example, religious institutions pay Rs 2/m^3 and industries pay Rs 25/m^3 for water (during the study period US$1.00 = Rs 58.80) (NWS&DB 1997b). To discourage the waste of water by domestic consumers, the tariff increases progressively by stages, depending on the amount of water consumed. For instance, for the first 10 m^3 Rs 0.60/m^3 and for all cubic meters above 50, Rs 32.50/m^3. The NWS&DB (1985) estimated the cost of supplying 1 m^3 of water in 1995 at Rs 0.95.

Economic Value of Water

Briscoe (1996) argues that there is an emerging consensus that effective water resources management includes the management of water as an economic resource. A way to do this is to establish water markets. Several conditions need to be met for establishing a water market. Among others, Meinzen-Dick and Rosegrant (1997), Perry, Rock, and Seckler (1997), and Reidinger (1994) all give a set of preconditions for the beneficial introduction of water markets. It is argued that markets increase economic efficiency by allocating resources to their more valuable uses (Bauer 1997). However, there are strong social norms that argue against water being treated as a simple marketable commodity because it is a basic need. Pursuing efficiency through market allocation may not be politically or socially acceptable if equity considerations are not met (Perry, Rock, and Seckler 1997; Meinzen-Dick and Rosegrant 1997). Besides the fact that water is an essential, life-supporting commodity with no substitute, water has some other complicating features, which make it more difficult to establish a market for it.

Water is

- a ‘fugitive,’ reusable good
- a common property or object of shared rights
- subject to economies of scale in provision
- associated with many non-market, environmental qualities (Morris et al. 1997; Caldas, Sousa, and Pereira 1997)

Since there is no developed water market in Sri Lanka, the value of water cannot be derived from the marginal value reflected on that particular market.

Water has an economic value because it has two qualities: desirability and scarcity (Abeygunawardena n.d.). In economics, the term “value” refers to monetary measures of changes in economic welfare (Young 1996). Economic valuation can be defined as the attempt to quantify goods and services provided by natural resources, whether or not market prices are available. The economic value of any good or service is generally measured in terms of the willingness to pay for the commodity, minus what it costs to supply it. Where a resource simply exists and provides us with products and services at no cost, it is our willingness to pay alone which reflects the value of the resource in providing such commodities, whether or not we actually make the payment (Barbier, Acreman, and Knowler 1997). The value of water, i.e., the desirability and scarcity, can vary considerably across seasons and regions. In Kirindi Oya, water will have a different value for farmers in the new and the old areas, during the maha and the yala seasons, and in wet and dry years. On a historic basis, the old area farmers claim that they have more rights on irrigation water than the new area farmers. The ID recognizes these rights and the old area farmers receive more water than the farmers in the new area. In this case, the value of water is influenced by the historical users’ rights, which determine the access and control over water, and this, in turn, influences the scarcity of water for certain users and uses. Hence, maintaining a constant value of water does not reflect the reality of changing water supply and demand conditions through time and region. Therefore, information on economic values of water must always be indicative rather than absolute (Pigram 1997).

Other Values of Water

Besides the economic value of water, it is also important to take other values into account when water allocation decisions are made. If only economic considerations and values would determine water allocation, the poor of the world could be very much worse off. For instance, willingness to pay depends largely on the ability to pay. Thus even with the same basic need or value of water, the rich will get more than the poor (Perry, Rock, and Seckler 1997).

Irrigation water has a ***social value*** in the sense that it creates opportunities for development. Without irrigation these opportunities do not exist. Consider, for instance, the *employment* generated by irrigated agriculture. It creates direct job opportunities in the field as well as indirect jobs that are linked with agricultural businesses and services. In Kirindi Oya, between 1986 and 1994 there was a decrease in agriculture-related employment opportunities due to the persisting drought and the consequent inadequate water supply (IIMI 1995a). Further, a decline of irrigation could also increase the trend of migration from rural to urban areas, which could enhance social conflicts. Besides employment generation and *social consistency,* irrigated agriculture contributes to *food security*. According to Fereres and Cena (1997) the risk of not maintaining a productive agriculture is a strategic mistake. A substantial decline in irrigated agriculture would make dry areas very vulnerable in the long run, regardless of the level of economic development.

The availability and the accessibility of irrigation water for domestic uses generate ***health benefits*****.** Respondents of the household survey in Kirindi Oya mentioned that there is a higher incidence of eye diseases and skin problems in the dry season due to shortage of water. Unfortunately, there were no data available to confirm these statements and the relationship between the availability and the accessibility of irrigation water and the incidence of these illnesses.

Besides this, irrigation water has an ***environmental value***. Examples include the recharge of groundwater table and preservation of the ecology of wetlands. This environmental use of water is especially hard to value because one has to deal with intangible aspects and some benefits only show in the long run.

Valuing the Productive Uses of Water

To value the productive uses of water like crop production, livestock, fisheries, and industries, the value added of water can be calculated. This is the so-called factor productivity of water and is defined in box 2.

BOX 2.
Formula to calculate the value added of water.

The value added of water is defined as: $\frac{\sum (PjQj - CjIj)}{W}$

Pj	=	price of output j; Qj = quantity output j; Cj = cost of inputs necessary to produce output j and
Ij	=	quantity of inputs necessary to produce output j; W = volume of water.

This is one way to measure the productivity of water for its different productive uses. The numerator shows the net value of output (NVO). Although it is harder to get data on the net value than on the gross value of output (GVO), it is worth the effort because if inputs are not deducted, all the value added is attributed to water, which doesn't reflect reality.

The value added for water can be calculated for three different levels:

1. Private farmers' viewpoint: shows the impact of water uses on a farm level and uses financial prices or those paid and received by farmers.

2. National viewpoint: shows the impact of different water uses from the national point of view, uses economic prices. Shadow prices or opportunity costs should be used when an environmental externality like damage to wetlands is included. It is possible to make a division into sectors like irrigation, municipal and domestic, industries, and the environment.

3. Global viewpoint: shows impact from the international point of view. For instance, impacts of water uses on maintenance of biodiversity, migratory birds, etc. It is hard to value those impacts. One way to value those impacts is the Contingent Valuation method (see annex 2).

Going from level 1 to 3, it is necessary to make more assumptions related to prices and impacts. For level 1, net values are essential, but for levels 2 and 3, societal perspective, gross values are suitable.

It can be hard to get an accurate measure of the volume of water used (denominator) by different uses especially when these uses include, for instance, reuse and non-consumptive uses of water. Another difficulty is the term "water use" itself. This could refer to irrigation diversions, crop evaporation and application, all having different meanings and implications. If the denominator reflects the water diverted, all the value added is attributed to irrigation water while rainwater also contributes to production. Furthermore, the amount diverted may be reused elsewhere. By taking the crop evaporation as the denominator, rainwater is included, so the value added is attributed to rain as well as irrigation water while the problem of reuse is eliminated. In box 3, different formulas are shown to calculate the value added per volume of water consumed, diverted, and the total water supply.

Unfortunately, there enough data were not available on small-scale industrial activities, like curd pot making and brick making, and therefore could not be included in the third formula in box 3.

Results of value added calculations for productive uses of water in Kirindi Oya are given in table 10. The gross value and the net value added of water are calculated from the farmers' point of view. Therefore, no cost is imputed for the use of land and family labor. The data used for the calculations come from different sources. The values of the denominator come from the chapter on water uses in the Kirindi Oya subbasin (chapter 3). With regard to the numerator, primary

BOX 3.
Value added of volume of water consumed, diverted, and total water supply.

1. Value added per m³ of water consumed refers to evapotranspiration (ET) and can be calculated for paddy and for OFC separately:

   (a) $\dfrac{\text{NVO paddy} \bullet \text{ha paddy}}{\text{volume of ET}}$ (b) $\dfrac{\text{NVO OFC} \bullet \text{ha OFC}}{\text{volume of ET}}$

2. Irrigation water is diverted to paddy and OFC cultivation, value added of volume of water diverted is:

   $$\frac{(\text{NVO paddy} \bullet \text{ha}) + (\text{NVO OFC} \bullet \text{ha})}{\text{volume of water diverted to irrigation}}$$

3. Total water supply includes irrigation water diverted and precipitation, and the different water uses are paddy, OFC, homestead, chena cultivation, livestock, and fisheries. Value added per m³ of total water supply:

   $$\frac{(\text{NVO paddy}\bullet\text{ha})+(\text{NVO OFC}\bullet\text{ha})+(\text{NVO homestead}\bullet\text{ha})+(\text{NVO chena}\bullet\text{ha})+\text{NVO livestock}+\text{NVO fish}}{\text{volume of water diverted and precipitation}}$$

To calculate Gross Value of Output per volume of water, replace NVO with GVO in the three formulas.

TABLE 10.
Value added per m³ of water for different productive water uses (in 1997 rupees).

	1995–1996		1996–1997	
	Gross value (Rs/ m³)	Net value (Rs/ m³)	Gross value (Rs/ m³)	Net value (Rs/ m³)
ET Paddy	7.2	3.7	7.1	3.6
ET OFC	38.9	30.7	46.9	37.1
Diverted water	3.4	1.8	4.9	3.2
Total water supply	1.7	1.0	2.4	1.6

and secondary sources were used. For paddy, it was possible to use the data from our household water use survey, although the survey was not designed for this purpose. Secondary data sources are used for OFC, homestead, chena cultivation, and livestock calculations (IIMI 1990 and 1995a; EA1P 1997). The key informant interviews provided supplementary data for livestock and fisheries. It is striking that data on homestead and chena cultivation, especially related to water use, are very scarce. To find the differences between wet and dry years, the calculations are made for 1995–1996 (wet) and 1996–1997 (dry). The values are all expressed in constant 1997 Sri Lankan Rupees (US$1.00 = Rs 58.80 in 1997) and calculated per m³ of water.

As shown in table 10, for ET, a distinction could be made for paddy and OFC. Since there are no separate scheduled water diversions for paddy or OFC and other uses like fisheries, it was not possible to distinguish the m³ diverted water for the specific uses. Consequently, also the total water supply has to be taken as one figure. In this case, OFC refers to a mixed cropping system of chili, groundnut, big onion, bananas, and vegetables. Paddy, as a high water-consuming crop, has much lower gross value and net value added per m³ ET than OFC. The OFCs cultivated in Kirindi Oya, especially onion and chili are high-valued crops. Hence, this results in higher gross value and net value added per m³ ET for OFC than for paddy. The differences between the values of a dry and a wet year are negligible for paddy but not for OFC. A possible explanation is that the composition of the OFCs is different for the dry and the wet years.

Compared to the value added per m³ ET, the gross value and the net value added per m³ diverted water and total water supply are quite small. As shown in box 3, the numerator of the formulas include more uses and are thus higher than the numerator of the first formula in box 3. However, the denominators of formulas 2 and 3 have much higher values. In the dry year (1996–1997), when there were less water inflow and rainfall, people were able to obtain higher value added per m³ of diverted water and m³ of total water supply than during the wet year (1995–1996). This shows that people have the tendency to use water more efficiently when there is less water available. Since the calculations are based on first order estimates and only for a 2-year period, we have to be careful with our conclusions.

Valuing the Nonproductive Uses of Water

A main hypothesis of this study is that the value of water for non-crop purposes will be of a significant magnitude when compared with the value for use in crop production, and it therefore follows that non-crop uses must be taken into account in the management of irrigation water resources. The limited literature and data availability on the subject of valuing water for other productive uses than crop uses give us the impression that these other productive uses are often overlooked and, therefore, hardly taken into account in water management decisions.

Moreover, we are not able to give a value for the domestic and the environmental uses of water, though for classification purposes we consider them as nonproductive uses. Hence, we cannot determine if the research hypothesis is accepted or rejected. These uses of water are not traded in markets and are therefore difficult to value. As shown before, the value of water for productive uses is assessed through the productivity factor of water for different goods. To value, and thus quantify the domestic and the environmental services of water, other methodologies have to be used (see annex 2). However, there are still problems and concerns related to the quantification of these services. One of the problems is the risk of missing the qualitative essence of uses (e.g., recreation) if intangible values and benefits of water are to be accounted for quantitively (Seckler 1966). Second, the willingness to pay is a function of the ability to pay. The value reflected by the willingness to pay is higher for people with a higher income. So it appears that people with a lower income attach a lower value to a certain service. This doesn't necessarily have to be the case. Third, according to conventional economic theory, monetary terms are used to analyze the efficiency of resource use. Efficient allocation of the resource, in this case water, does not have to be compatible with sustainable use and equitable distribution (Bingham et al. 1995). Therefore, it is important that water allocation decision makers do also take into account other information than only the quantitative values of water.

Conclusions

Values presented in this chapter are based on first order estimates of water accounting. Because of this, together with the lack of data available on other productive uses of water than crop production and data on domestic and the environmental values of water, the values in this chapter should be seen as a first indication and not as absolute values of water. Further, substantial productivity gains should be expected if ways could be found to save and utilize the water lost to the ocean (see chapter 3).

With the value-added method, we are only able to calculate the value of water for productive uses, where water is consumed. To value the domestic and environmental uses of water, other methodologies should be used. The next step is to look for suitable methodologies and to operationalize and apply these for the Kirindi Oya case study. Supplementary data should be collected, for example, data on positive and negative impacts of irrigation water on the wetlands and the time spent in fetching water from different sources for domestic purposes. We will be able to test our main hypothesis, only if we are able to calculate the value for the domestic and the environmental uses of water.

8. Complementarities, Competition, and Conflicts

Agriculture remains the largest consumer of water in the Kirindi Oya system, particularly paddy. Many of the other uses such as fishing or bathing are nonconsumptive, while others such as drinking, watering livestock, collecting lotuses or reeds, and brick making consume relatively small amounts of water compared to field irrigation. Because they draw their water directly from the irrigation system (canals and tanks) or indirectly (from wells through groundwater recharge), there is a complementarity between these uses and field irrigation. When water is available in the tanks and canals for paddy fields, it is also available for gardens, fishing, lotus production, bathing,

TABLE 11.
Conflicts, competition, and complementarity of water uses in Kirindi Oya.

	Irrigated crops	Live-stock	Fishing	Laundering and bathing	Drinking	Home industry	Home gardens	Environ-ment
Irrigated crops	•	–	–	–	–	–	–	–
Livestock	•/+	x	–	–	–	–	–	–
Fishing	•/+	•	x	–	–	–	–	–
Drinking	•/+	x	x	•	•	–	–	–
Laundry bathing	+	•	x	x	–	–	–	–
Home industry	•/+	x	x	x	•/+	x	–	–
Home gardens	•/+	x	x	x	•	x	x	–
Environment	•/+	•	•	x	x	x	x	•

• conflicts and competition
x no conflicts and competition
+ complementarity

livestock production, curd pot making and brick making. Moreover, when water is abundant, water quality problems are also reduced. When there is no water for irrigation, agro-wells dry up, fish stocks are depleted, milk production decreases, lotus stems must be removed, domestic water is unavailable from the canals, wells fall dry, and the pollution and salinity concentrations of the remaining water increase.

When water becomes scarce, there is more competition, and even conflicts over water. From an analytical perspective, the different types of uses compete. However, from the households' perspective, this competition is not so much between sectorally defined *uses,* because all households engage in multiple activities involving water. Within the household, some members may be more affected by the shortage (or benefit from abundance) of water for certain uses than others. The overall perception of competition is between *users*—particularly between the old and the new areas.

Competition, Complementarity, and Conflict between Uses

The major types of interactions between different types of uses are summarized in table 11. Because irrigation of field crops is the largest water user, and holds the strongest rights to water, the relationship between each use and irrigated crop production is the most important form of interaction. However, the potential positive and negative interactions between other uses may also be significant, as indicated below.

Irrigated Crop Production

The chief competition and conflict in Kirindi Oya are not between the different types of uses, but regarding irrigating fields in the old and the new areas. There is an ongoing tension between the demands of the Ellagala area for full paddy irrigation in two seasons, based on their historical claim to water, and those of the different parts of the new area to receive water for paddy in at least one season. Although broad priorities have been set, fluctuating weather and hence water availability require renegotiation of the areas that can receive water in each season. Despite the seasonal allocation process through the PMC, there have been tension and conflict, particularly in years of low rainfall and reservoir inflow. Even within the old or the new area, there may be competition between the fields that get irrigated, especially when water supplies are short.

In terms of water quality, there are also significant negative interactions between irrigated fields at the local level. The salinity problem due to poor drainage is becoming more evident in Kirindi Oya, as discussed in the chapter on water quality issues (chapter 4).

Livestock

When the Kirindi Oya system was expanded, it displaced a considerable number of livestock that had been using the area for grazing and watering. Much of the ongoing competition between irrigated crops and animals relates primarily to grazing, rather than to water per se. Crop damage from cattle is a recurring tension. While the volumes of water consumed by the animals are not a significant source of competition, conflicts over watering animals arise because cattle damage the irrigation infrastructure.

At the household level there is some complementarity between crops and livestock, because water in the irrigation system makes water more available for animals as well. The farming system includes both crops and animals, with crops providing fodder, and animals providing draft power and manure. Use of irrigation facilities by livestock is tolerated, as long as they do not damage crops.

Fisheries

At one level there is considerable complementarity between irrigation and fishing. The reservoir, tanks, and canals of the irrigation system provide the environment for fish production, and fishing provides a fallback occupation for some agricultural households during difficult times. However, the pesticides used for paddy and other irrigated crops flow into the water. Fish and other aquatic animals are very susceptible to changes in water quality. Furthermore, low tank water levels reduce the number and diversity of fish species. “Optimizing” the use of tank water for irrigation purposes by reducing the level of dead storage or the amount of water stored in lower tanks during the season (to take advantage of return flows from upper irrigated fields) may reduce the potential for fishing.

Drinking

In terms of water quantities, there is a complementarity between irrigation and drinking water, especially in the old area, where wells and seepage from surface irrigation sources provide the main source of drinking water. However, in dry years, irrigation and drinking compete for water. The biggest conflict is generally over the right of the NWS&DB to keep the water in the reservoir at a certain level to guarantee domestic water needs through the piped water supply system. Irrigation supply was stopped to safeguard domestic needs in 1992 which led to serious conflicts. Farmers demanded for more water releases for irrigation, and politicians got involved in trying to settle the disputes (Brewer, forthcoming). These issues resurfaced in 1995 and 1997.

There is more conflict between irrigation and drinking uses when it comes to water quality. Agrochemical runoff and leaching of minerals as water seeps and percolates from paddy fields have contaminated both surface sources and groundwater within the Kirindi Oya system, making well water unsuitable for drinking.

Laundering and bathing

Irrigation and bathing and laundering are largely complementary, because canals and tanks are very important sources and locations for these domestic water uses. When irrigated crop production takes place, there is more water available for bathing and laundering, and since the latter are in-stream uses, they do not take water away from field crops. There can be, however, conflicts over water quality, as high salinity levels make the water less suitable for laundering and bathing.

Home industry and home gardens

The interaction between field irrigation and home gardens (household industries) is largely complementary. The latter use relatively small amounts of water, which usually come from rainfall or the irrigation system (either through pumping of water from canals or recharge of wells). In some instances, there can be a conflict if people at the head of the canal use the water for home gardens or home industries and thereby reduce the water availability for the tail enders' fields.

Environment

The availability of water in the irrigation system has provided a habitat for wildlife, especially birds. The Weerawila tank was designated as a bird sanctuary before the expansion of the irrigation system, and despite predictions that birds would be displaced, their population has actually increased. However, eutrophication of the tank is becoming a problem for wildlife—caused in part by fertilizers, and also by livestock. While wading birds do not cause much conflict with crop production, intrusions by elephants from nearby wildlife areas looking for water cause conflicts resulting in crop damage.

Water quality issues are even more important in the neighboring Bundala National Park. In addition to eutrophication causing excessive growth of algae, there are problems maintaining the salinity balance in the lagoons if there is too much discharge from the irrigation system. Two brackish lagoons have been converted into freshwater lakes. This has had a negative impact not only on water birds, but also on the hundreds of families that were formerly engaged in prawn fishing in the lagoons.

Livestock

Fisheries

Since neither livestock nor fisheries consume much water, the interactions with respect to quantity are negligible. However, livestock pollutes the water with dung and urine. This can cause eutrophication, which can have a negative influence on the fish (although some species thrive under such conditions).

Laundering and Bathing

As in the case of interactions with fisheries, livestock pollutes water. Since people enter the tanks and canals to bathe and launder, the dung and urine from livestock can cause a public health risk. The negative effect on bathing and laundering is especially pronounced when the water level is low.

Environment

Conflicts between livestock and the environmental interests over access to tank areas and land have led to a number of disputes between the COFO and the Wildlife Department. In terms of water quality, there are further conflicts because overgrazing and deposits of dung and urine in the water can cause eutrophication, especially in the Bundala lagoons.

Fisheries

Environment

In some of the tanks and the Lunuganwehera reservoir, conflicts arise between the Department of Wildlife Conservation and the Fishermen Cooperative Societies. These conflicts relate to access to the tank areas in the evening (and thus disturbing wildlife) which is the preferred time to fish.

Drinking

Although the total amount of water for drinking and cooking is relatively small, this water is very important to satisfy basic human needs, and there is not always enough available at the standposts. Thus, conflicts between different users arise at the tap.

Laundering and bathing

When there is no water available in the canals, people use the tap water also for laundering and bathing. This is prohibited by the NWS&DB (NWS&DB 1997a), and causes conflicts because if some take water for bathing, there is less available for others at the standpipe, and the additional costs are borne by all.

Home industry and home gardens

As in the case of interaction between drinking and bathing, when the tap water is used for gardens or home-based industries, conflicts arise because people use more than they are supposed to, which leads to longer queues and higher costs for others at the standpost. However, there is also a strong complementarity between drinking (and especially cooking) water and home gardens, because wastewater is used as a source for gardens. Surplus water spilled at the standpipes is also often channeled into nearby gardens.

Environment

Salinity in paddy fields has become a significant environmental problem in certain parts of the command area. But mitigating this problem through leaching and drainage displaces the minerals and solids, which can cause problems in other areas, including domestic wells and the wildlife sanctuary.

Interaction between Users: The Household Perspective

Paddy production is the primary source of livelihood for many people. Thus, most people (especially those in households with at least some paddy fields) are more concerned with the allocation of water between different areas (primarily for irrigation) than between different uses. However, the potential complementarity between irrigation and other uses should not be overlooked. When water is released in the canals and tanks in an area to supply crops, it is also available for livestock, fishing, gardens, bathing, and other enterprises. Not all members of a household have an equal interest in all types of water use. Men, women, and children have different responsibilities related to each type of water use, and derive different benefits.

While water quantity issues continue to be the most prominent, there is considerable awareness of water quality problems, particularly for drinking and bathing. People complain not only of the palatability of water, but also of its hardness. They are also aware of the role of agricultural chemicals and seepage in contributing to water quality problems. However, this does not prevent them from using chemicals on their own fields. Since runoff upstream is what affects each area's water quality, a family would not benefit, in terms of water quality, from refraining from chemical use. Because the problem is not localized, local collective action is also unlikely to have an effect. Addressing the water quality problems—for the benefit of both household use and the environment—would require more widespread regulation.

9. Future Directions for Research

Introduction

In the classical sectoral approach to irrigated agriculture, the irrigation infrastructure, management, and institutional arrangements serve the objective of efficient use of water for food production. In this report we have argued that such a sectoral view that does not take into account water uses pertaining to other sectors is too limited in scope. The sectoral approach is more and more replaced by the concept of Integrated Water Resources Management (IWRM). While the theoretical concept is still developing, it seems that IWRM takes water as a natural resource as the starting point and then analyzes how this resource can be managed in an integrated and sustainable way by building institutional capacities to satisfy human needs, promote food security, and protect the environment. Our approach of looking at the multiple uses of water differs from IWRM in the sense that it is more anthropocentric, i.e., it starts with the question: who are the users of water and what are their uses? It puts the people, the multiple users of water at the fore while appreciating that people operate in a certain physical and institutional environment. It documents why certain sources are preferred above others, how people cope with periods of drought, and analyzes how far the tasks in relation to water are gender-specific. Finally, it tries to estimate the value of different uses of water. We think that such an analysis of the multiple users and uses of water should precede any attempt for implementing IWRM.

Research Methodology

A combination of qualitative and quantitative methods as used in the present case study will remain the best option to describe the different water uses at the sectoral and the household levels. While certain patterns are likely to be representative for other areas of Sri Lanka, variations between countries will be considerable. The methodology for the systematic documentation of multiple uses of water has to be refined further and applied elsewhere. While most of the information required to describe multiple uses and users of water could be obtained with the methodologies used in this case study, the procedures were rather labor-intensive and time-consuming, especially the household interview survey. More efficient research methods should be considered. Ideally, these would be rapid assessment and even participatory appraisal procedures that can validly describe sectoral and household level water uses and users (Gosselink and Thompson 1997; Chambers 1994; Gosselink and Strosser 1995; Pretty et al. 1995).

In reviewing the output of the present study, a lot of descriptive information was available through key informant interviews and direct observations in the field. Another point of attention in further studies should be the validity of interview-based data. To quantify use and users at the household level, direct observations could provide more reliable data than household interviews, but at a greater cost. Methodologies for direct observations could be obtained from the extensive literature that is available on human water contact studies in relation to schistosomiasis (see for example Kloos et al. 1983). Provided a valid sampling frame is used, such studies can also give a better idea of gender-based water use than the household interviews. Group discussions, when used at the beginning of a case study, can be a useful exploratory process when little is known about the study population. They make it easier to compile a questionnaire for collecting quantitative data or recording sheets for water contact observations. This would prevent the gathering of exhaustive, irrelevant information. However, the quantitative data collected through household interviews can still be difficult to interpret, owing to the complexity or ambiguities they contain. A second round of group discussions at the end of the case studies can then provide a fuller understanding of the numerical results, and provide relevant feedback to people in the study community.

Research Priorities

Measuring Water Use and Economic Values

In the discussion on competition for scarce water resources in water basins with multiple uses, it is very important to be able to assign economic values to the different uses. While techniques (see annex 2) exist for valuing water for economic uses, as seen in this study, they are often cumbersome and expensive to apply. Simpler, but robust techniques are needed, not only for research purposes, but to ensure that the valuation methods are understood by system managers and policy makers. Further, there is a lack of data regarding the inputs and outputs of production for water uses other than the main field crop (e.g., chena cultivation, fisheries, etc.) and it is recommended that more time and effort are put in gathering this kind of data.

One common feature of all types of economic valuation is the denominator: water use. Getting an accurate measure of water use by different sectors can be difficult (if not impossible), especially when the uses include return flows, reuse, and nonconsumptive use. Adding to this complexity, the term “water use” has different meanings to different people and could refer to (irrigation) diversions, application, or evaporative use, all having different implications. This study has suggested a means to account for water use by different users in a consistent manner. It would be useful to refine and adapt this method to other situations so that it can have broader applicability.

Valuing the Nonproductive Uses of Irrigation Water

As complicated as it is to estimate the value of water used for productive purposes, it is much more difficult for the nonproductive uses; domestic and the environmental uses. In fact, methodologies for valuing nonproductive water uses are existing but they are applied only in relation to a single sector or use of water, either the domestic use (Altaf, Jamal, and Whittington 1992; Whittington and Swarna 1994) or the environmental use (Barbier, Acreman, and Knowler 1997). Further development and testing of such methodologies and developing a framework for valuing water in an integrated water resource system are priorities for further research. Like with all aspects of multiple use, this should be an interdisciplinary effort. A lot of useful information on the value of uses in a particular sector might be available in the specialized literature. An example is the cost-of-illness methodologies developed for water-related diseases.
An extensive interdisciplinary literature review is therefore needed, including less traditional literature sources, before designing new studies.

Water to Sustain Aquatic Ecosystems

The environmental functions of irrigation water will be addressed in a follow-up to the present Kirindi Oya case study. Irrigation drainage water affects the important wetland ecosystem of the Bundala National Park. The aim is to develop a methodology that could be applied elsewhere and that could address the following questions:

- How does irrigation water management affect the ecology of downstream wetlands?
- What are the water management options that could conserve wetlands?
- What are the water use options that will best serve the interests of different users, especially those of poor rural communities?

Water as a Basic Human Need

A case study similar to the one in Kirindi Oya was completed in Pakistan (Jehangir et al. 1998). The main objective of that study was to get an accurate assessment of all the uses and users of water in the irrigation system. In the study area, people depend on irrigation water for all their domestic requirements, even for drinking. Therefore, in Pakistan, health impacts are more important issues than in Sri Lanka. To bridge the gap between irrigation and the domestic water supply sector, a detailed epidemiological and water quality study has now been started. In Pakistan and elsewhere, we want to address the following questions with respect to water as a basic human need:

- To what extent is irrigation water used for domestic purposes?
- What is the health impact of these domestic uses of irrigation water?
- What adaptations in irrigation system design and operation are needed to make domestic use of irrigation water a safe option?
- How will more efficient irrigation and “improved” irrigation water management practices affect the quantity and quality of water available for domestic purposes?

10. Conclusions: Implications for Policy and Management

Introduction

Disciplinary and subsectoral emphases have too long focused the attention of researchers, policy makers, and agency staff involved with water resources on only one of the following water uses—irrigation, domestic use, fishing, or livestock—when in fact, people have been using water in irrigation systems for many purposes. Going beyond the disciplinary and sectoral blinders changes our picture of irrigation systems and allows us to see the full spectrum of water uses. It also expands the view of water users beyond those (primarily male) farmers in the fields or those (primarily women and children) drawing water at the standpipe. In this study, we have seen how fishermen, livestock herders, and curd pot makers, and even the birds and animals are water users who depend on the irrigation system for their livelihoods.

Recognizing the full spectrum of uses is far more than an academic exercise. It has important implications for the management of water within the irrigation system, and also for a broader water resource policy. The present study has been only a pilot activity, and could not explore and quantify all the water uses and their values. Nevertheless, it points to critical issues to be addressed. This concluding chapter identifies a number of these issues, within Kirindi Oya, and then addresses policies such as intersectoral allocation and infrastructure development.

Management Issues within Kirindi Oya

The allocation of irrigation water between different parts of the Kirindi Oya system continues to be the single most important management issue, even if multiple uses are taken into account. It is not so much that a rising tide lifts all ships, but that an irrigation release fills all pots, meets most other water needs, and dilutes the contaminants. When water is scarce, cutting back on irrigation to reserve water in the reservoir and providing special water releases in the canal and river for domestic supply become critical decisions that have provoked considerable conflicts in the past.

The issue of the water level that should be maintained in the tanks is another management decision, which illustrates some of the potential trade-offs between different uses. Keeping the tank levels high during the maha season causes considerable spillage, which is not recaptured, and water flows out of the system to the ocean. If the tank levels were kept lower, more of the rainfall and drainage from the new area could be recaptured. This would be more efficient from the standpoint of irrigation, because the same area could be irrigated with less reservoir releases, saving water for other areas or for the next season. However, the lower tank levels would reduce the availability of water for bathing, washing, livestock, and fishing in the tanks. Moreover, reducing the water levels in the tanks and relying more on recycling would increase the concentration of various contaminants (including agrochemicals and fecal coliform bacteria). On the other hand, conserving water would reduce the problems in getting water for domestic and other uses in the yala season, when water is usually very scarce, and the reduction in drainage would allow the Bundala lagoons to remain brackish for prawns and other fauna that depend on the original brackish conditions. Considering all the uses of water complicates the decision-making process because it shows that maximizing the efficiency for irrigation may not be the same as “optimizing” for all uses.

From a household perspective, it is unlikely that a reduced quantity of irrigation water allocated to the system has a major impact on the household supplies of water for drinking, cooking, sanitation, and the washing of utensils. However, in the long term, reduced seepage of irrigation water may have an impact on the availability of water in the homestead wells and thereby affect water availability, for instance, for sanitary purposes. A reduced availability of water in the canals and tanks will have a significant impact on the availability of water for personal hygiene, laundering, and recreational use. The impact will differ throughout the system, where some families will be able to shift their priority to other sources, while many families living in areas with poor piped water supply will definitely feel an impact on their households. The impact of a reduced irrigation water supply will increase the pressure on the piped water supply throughout the system, especially in the areas where the groundwater is brackish. This is likely to lead to increased conflicts between the users of the standpipes. Another possible general impact is a reduced overall per capita use of water for hygiene practices.

Water rights in Kirindi Oya are not clearly defined, especially for uses other than irrigation and domestic supply. The PMC has the responsibility for water allocation, but despite the range of government and user organizations represented, it has not recognized the range of water uses, or the challenge of managing water to meet all needs.

Because many of the water uses are nonconsumptive (e.g., fishing), or require relatively small amounts of water (e.g., curd pot making), they do not compete with other uses in terms of the volume of water, and as long as water is relatively abundant, it is not worthwhile to define a quantitative right. Although many of these uses may not directly conflict with one another, when water demand increases, or when water supply decreases, competition for water resources follows. For many uses, quality issues are often more important than quantity (e.g., domestic water, fishing, or wildlife). Hence, the critical rights are not for withdrawal, but for management of the resource (and potentially for exclusion of other users that pollute). For example, fish is highly sensitive to salinity and agrochemical pollution, and its production is reduced when water levels in the tank are too low or too high. Thus, although fishing is a nonconsumptive water use, fishermen have a strong interest in the management of tank water levels, and in the interactions with other uses. However, the rights and coordination mechanisms to deal with such issues are not defined at present.

Finally, considering the interactions among the multiple water uses highlights the issues of water quality. These are critical not only for domestic use, but also for fishing and the wildlife. At present, there is virtually no attention given to water quality. Measures to handle sewage and livestock wastes are ineffective, and there are no measures to limit contamination from agrochemicals. Experience in industrialized countries has shown that it is difficult to handle such nonpoint source pollution. However, raising awareness and discussing the issues are necessary if the water of Kirindi Oya is to continue to support multiple uses.

Implications for Water Management Policies

While the exact uses and users of water and their relative importance vary from one irrigation system to another, the issues identified in this pilot study in Kirindi Oya have broader implications for water management policies in Sri Lanka and elsewhere. These relate to the allocation of water and financial resources between irrigation and other sectors; measures of water quality and efficiency of use; and mechanisms to involve all stakeholders in negotiations over water use.

With the growth of cities and industries and the relative decline of agriculture in economies around the world, inter-sectoral competition for water has become a major issue, and irrigation systems often lose out relative to municipal and industrial uses. Inter-sectoral water allocation is generally viewed as a process of determining how much water goes into a municipal system, a factory intake, an irrigation system, or natural reserve—implicitly or explicitly equating domestic use with municipal systems, industrial use with (licensed) factories, agriculture with irrigation systems, and biodiversity or environment with wetlands and reserves. This study has demonstrated that water in the Kirindi Oya irrigation system is used for much more than simply producing the field crops, which is often attributed to irrigation. Although an exact quantification is extremely difficult, the social and economic value of water within the irrigation system is much higher when we account for all uses, than is recognized in many conventional analyses of inter-sectoral water uses.

Because of Kirindi Oya's distance from major urban centers, municipal and industrial uses have not been major competitors with irrigation for the water resources available in the system. There are plans to build an oil refinery on the coast, which would require substantial allotments of water every day from the Kirindi Oya system. Recognizing the multiple uses of water changes the analysis of inter-sectoral water allocation, especially for reallocation out of irrigation. A simplistic analysis might suggest that the water needed for the refinery could be met by improving the "efficiency" of irrigation deliveries, taking a certain area out of paddy production, or a combination of these approaches. A more comprehensive view would recognize that changing the quantity and timing of water deliveries to supply such a major industry would not only affect system managers or the farmers who have to switch crops but also the other users of water. It would have ripple effects throughout the system, affecting groundwater levels and hence water availability for drinking and homegardens; tank levels and hence fish production; runoff and hence concentration of chemicals; and salinity entering the wetlands, among other factors.

Water for hotels to meet a growing tourist industry is also a serious current issue of water allocation within Kirindi Oya, and illustrates another aspect of inter-sectoral water use: the impact on water quality. Although hotels, like other domestic uses, may not deplete water supplies as much as agriculture, they create wastes that can contaminate downstream water. Currently, the ID has denied requests for surface water allocations to hotels, but there has been no effective restriction on groundwater abstractions. Mechanisms for monitoring such abstractions and the impact of their uses on water quality are currently weak. Dealing with these aspects of water resource management requires going far beyond the existing sectoral approaches to developing irrigation or domestic water supplies.

As water resources become more fully developed, countries often turn from investments in new systems for water capture and storage to improve the efficiency of existing water supply systems (particularly irrigation systems). Canal lining, sprinkler or drip application systems, and rotational irrigation schedules are common means of increasing the proportion of water in the system that is used for crop evapotranspiration. The water "saved" through these measures is then seen as available for reallocation to other uses or users (e.g., expanding the area irrigated or supplying to municipal systems). But reducing the seepage and percolation through canal lining or sprinkler and drip systems often lowers water tables, affecting the wells for drinking and gardens. In places like Kirindi Oya, where permanent vegetation relies on high water tables recharged by irrigation seepage, such measures could also threaten quite a bit of high-value horticultural production (e.g., coconut, mango). Rotational water deliveries could also create problems for livestock and bathing; the crops may be able to go on for days or even weeks between waterings, but people and animals who depend on the canals as sources of bathing or drinking water need the water on a daily basis. This is to conclude that when measures are taken to improve irrigation efficiency, the impact it may have on other water users also needs to be taken into account.

Recognising the various uses and users of water is an important step toward managing the system to accommodate all needs. However, trade-offs between different uses are inevitable. In such instances, decisions can be externally made (e.g., by a government agency), or can be negotiated among various stakeholders. The latter has the potential to reach decisions that are more acceptable to a range of parties, but it requires some form of platform for negotiation (Röling 1994; Steins and Edwards 1998). The government has been striving to devolve management and increase user involvement, and the establishment of a range of formally recognized user organizations (e.g., the hierarchy of FOs, COFOs, and FCSs) can be seen as a step toward establishing a platform for negotiation within a single use sector. Institutions such as the PMC, which bring together farmer representatives from various parts of the system along with representatives from a range of government agencies, can provide a platform for negotiation over the use of water for irrigating field crops. It may be possible to expand the PMC, which currently includes government representatives from a number of agencies, as well as farmers and livestock owners' user groups, to represent other interests such as fisheries, domestic water, and the environment. Bringing in representatives of other categories of users can be done through public meetings to discuss water management plans, either on a seasonal basis, or especially whenever management plans are suggested.

To the extent that the members of the FOs also use water for domestic purposes, gardens, and even fishing, it might appear that these other types of uses could be represented by the farmer representatives. However, experiences from Kirindi Oya in 1992, 1995, and 1997 show that at critical times, the farmers give priority to water for irrigating the field crop instead of giving priority to water for domestic purposes. While farm households may be involved in all of these uses, there are important intra-household differences in responsibility for these various types of uses. Membership in the FOs at all levels is heavily dominated by males (Meinzen-Dick and Zwarteveen 1998). Even though the interests of men and women are often complementary, there are important differences in priorities for water use (Zwarteveen 1994). Thus, the significant barriers to gender equity in participation should be addressed for effective overall management of all water uses.

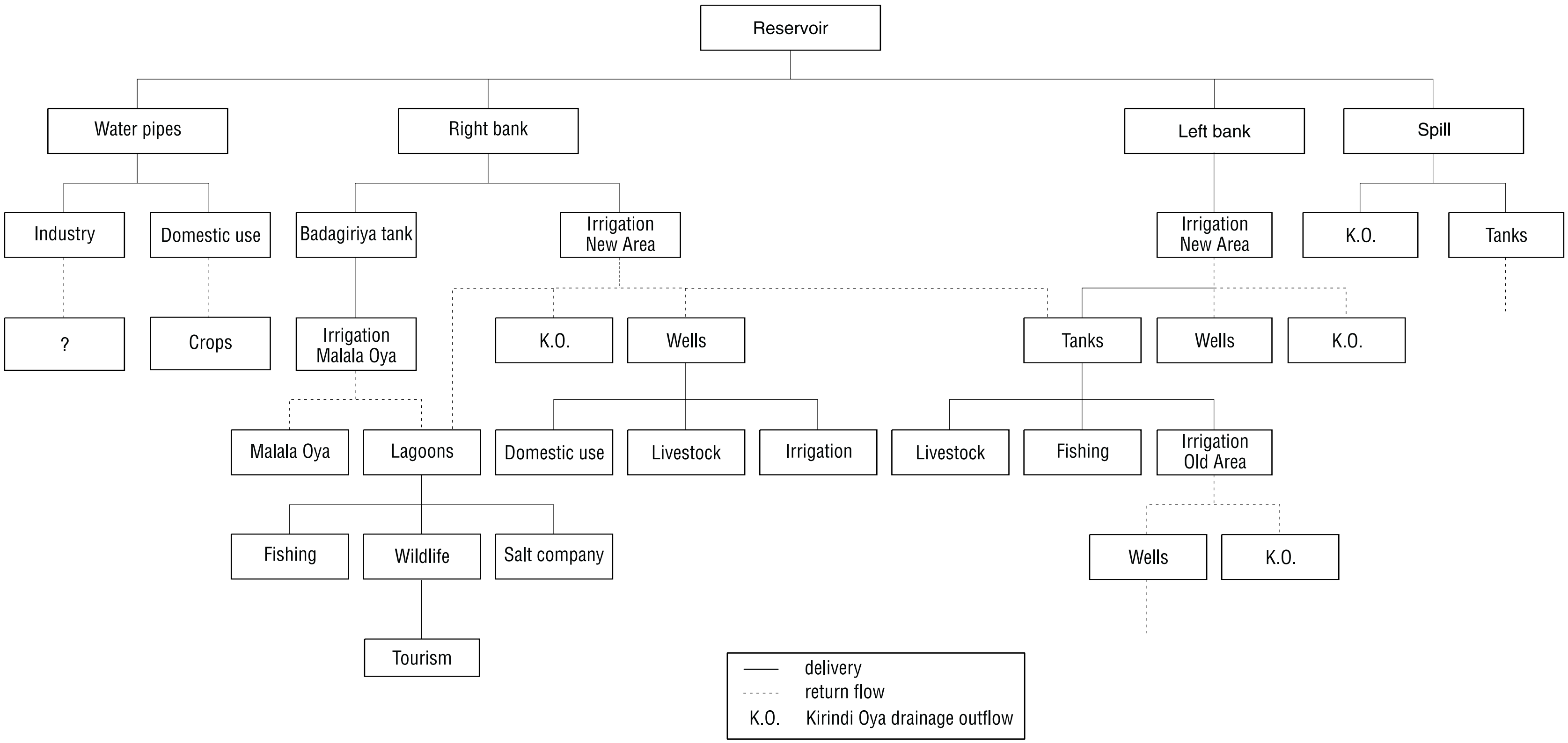
The twelfth century Sinhala King Parakrama-bahu I is quoted as saying:

> *Let not even a small quantity of water that comes from the rain flow into the ocean without being made useful to man.*

If we recognize the multiple uses of water, we see that, while some water still runs to the sea, much of it is used by men and women, several times over. This undoubtedly increases the value of water use, and it needs to be taken into account when evaluating irrigation system performance. But in the process of being used for so many purposes, the water picks up a variety of contaminants, such as fertilizers, pesticides, salinity from the fields, soap residues, bacteria from domestic and livestock uses, and other types of chemicals. Recognizing the interactions between uses and users may also provide scope to better accommodate the various uses, thereby to increase the efficiency of water use. But to increase the total value of productive and non-productive uses within irrigation systems, more attention should be focussed on water quality issues, as well. Unfortunately, as difficult as it is to develop accurate empirical measures of quantitative efficiency or system performance, it is even more difficult to measure and incorporate measures of water quality. On the output side, the uses that are particularly susceptible to water quality (especially drinking water and wildlife uses) are very difficult to place quantitative values on. This remains a critical area for further research as well as for action in water management.

ANNEX 1

Water flow chart



ANNEX 2

Other Valuation Techniques

Alternative Costs/Opportunity Costs

If a given water allocation with specified output costs less than the next water allocation which can achieve the same output, then the cost of the next-best option can be considered as the benefit to the water allocation under consideration. This method may be a solution when estimations of a direct demand schedule prove to be difficult because of lack of data or other reasons. This is similar to the opportunity costs calculation, which calculates the benefit foregone by using a scarce resource for one purpose instead of its next-best alternative use. The benefits foregone can be used to value the water for that purpose. An aspect which can be taken into account when using this methodology is the quality of water because this influences the suitability of the water for other purposes and thus affects the number of (next-best) alternative uses. This is important to note because water quality issues are often ignored.

This method can be used to value the domestic water use from different sources. In the villages in Kirindi Oya, there are several water sources that are used for domestic uses. Each water source has its own characteristics (distance from the house, quality perceived, reliability, etc.) and is selected for different uses (see also chapter 6). According to Whittington and Swarna (1994), water from different sources is a different good in terms of quality and service characteristics. Water from different sources is a close but not a perfect substitute. The costs consist of resource costs plus a money price of obtaining water from that source. For a public tap, for instance, this includes the opportunity cost of time spent walking to the tap, waiting in the queue, walking home, plus the price paid for tap facilities. The total costs will vary among households, as the opportunity cost of the time spent for collecting water will be different depending on the distance from the water source. This will result in different water values for water from different sources.

In addition, this method can be useful to value the water for agricultural crop and non-crop production like fisheries, industrial use, and the environmental use (recharging groundwater table).

Contingent Valuation Method

Another way to value water, often applied when services are improved is the Contingent Valuation Method. This method determines the market value by trying to get people to reveal what they would be willing to pay for water and services in hypothetical markets. Individuals are surveyed to determine their willingness to pay for a specified change in the quality or quantity of water. The mean value of the willingness to pay across all bids (including valid zero bids) is then used to provide an indication of the economic value of the specified change. The quality of the results of this method depends on how well-informed people are; it does not adequately incorporate long-term goals since it excludes future generations from bidding in the markets. It is also difficult to induce individuals to reveal their true willingness to pay for natural resources when the question is put directly (Erskine 1997). Potentially, serious biases could arise from the use of this method and the estimates derived should be viewed as broadly indicative, rather than knowledge-based (Pigram 1997).

This method can be used to reveal the willingness to pay for improved water quality from the wells or reliable water supply from the standpipes in Kirindi Oya. Altaf, Jamal, and Whittington (1992) applied the Contingent Valuation Method in the Punjab, Pakistan. They used the methodology to determine the willingness of the households to pay for improved service levels. It is also possible to apply the Contingent Valuation Method for agricultural crop production. Farmers, especially in the new area can be asked what they are willing to pay for a more reliable irrigation water supply. Further, this methodology is applicable to agricultural non-crop production, industrial, and recreation/environmental water use. For instance, people can be asked what they are willing to pay for preserving the wetlands in Bundala or for having a bath in one of the tanks.

Hedonic Pricing Method

This method is based on the concept that the price paid for a complementary good (e.g., a residential property) reflects the buyer's willingness to pay for a particular environmental good (e.g., adjoining a river). Application of this method requires the use of regression analysis to determine the relationship between the market price of the property and its attributes, of which one (set) relates to associated environmental characteristics. From this, the implicit price for the associated environmental characteristics is derived. This method rests on the assumption that the price of some marketed good is a function of its different characteristics, and an implicit price exists for each of the characteristics (Young 1996). So, it is necessary that active and competitive agricultural land and real estate markets are in place to use the Hedonic Pricing Method. In Kirindi Oya, agriculture and real estate markets are not active and competitive. If these preconditions are there, land values can be derived from samples of land sales representing irrigated and nonirrigated land. A comparison of the irrigated and the nonirrigated land values can provide a useful and relatively convincing information about the revealed preference for irrigated land. The difference between the value of irrigated and nonirrigated land represents the value of irrigation water.

Travel Cost Method

This method is based on the concept that people spend time and money traveling to recreational sites and that these expenditures, or costs, can be treated as revealing the demand for the site. Surveys of site visitors are undertaken to determine the demand for a site. Visit rates are a function of travel expenditure, income, entry fees, environmental characteristics and the availability of substitute sites (Postle, Berry, and Westscott 1997).

The Travel Cost Method might be useful to value the Bundala National Park which is part of the research area. However, the money spent on

Suitability of valuation techniques in the Kirindi Oya case study.

	Agriculture		Fisheries	Domestic	Industry	Recrea-	Environ-
	Crop	Non-crop				tion	ment
Alternative cost/ opportunity cost	✔	✔	✔	✔	✔	✔	✔
Contingent valuation	✔	✔	✔	✔	✔	✔	✔
Hedonic pricing	–	–	–	–	–	–	–
Travel cost	–	–	–	–	–	✔	✔

traveling and entrance fees reflects the value of the recreational site as a whole and not just the value of the water that it contains. So, when using this methodology to value the water in Bundala National Park, the water will be overvalued (Burrill 1997).

The table below gives an overview of the methodologies described in this annex, and the suitability to apply those on the different water uses in Kirindi Oya.

Literature Cited

Abeygunawardena, P. n.d. *Total economic value of forests: The case of Sinharaja Reserve in Sri Lanka*. Sri Lanka: Faculty of Agriculture, University of Peradeniya.

Altaf, A., H. Jamal, and D. Whittington. 1992. *Willingness to pay for water in rural Punjab, Pakistan.* UNDP-World Bank Water and Sanitation Program. Water and Sanitation Report No.4. Washington, D.C., USA: The World Bank.

Barbier, E. B., M. Acreman, and D. Knowler. 1997. *Economic valuation of wetlands. A guide for policy makers and planners.* Gland, Switzerland: Ramsar Convention Bureau.

Bauer, C. J. 1997. Bringing water markets down to earth: The political economy of water rights in Chile, 1976-95. *World Development* 25(5):639-656.

Bhatia, R. 1997. Food security implications of raising irrigation charges in developing countries. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Bingham, G., R. Bishop, M. Brody, D. Bromley, E. Clark, W. Cooper, R. Constanza, T. Hale, G. Hayden, S. Kellert, R. Norgaard, B. Norton, J. Payne, C. Russell, and G. Suter. 1995. Issues in ecosystem valuation: Improving information for decision making. *Ecological Economics* 14(1995):73-90.

Brewer, J. D. 1994. The participatory irrigation system management policy in Sri Lanka. *Economic Review* 20 (6):4-6, 8-9.

Brewer, J. D. Forthcoming. Negotiating water allocation rules in a government managed irrigation system: Conflicts in Kirindi Oya. In *Negotiating water rights,* eds. B. Bruns, and R. S. Meinzen-Dick. New Dehli: Sage.

Briscoe, J. 1996. *Water as an economic good: The idea and what it means in practice.* Special Session R 11, Sixteenth Session. Cairo, Egypt: International Commission on Irrigation and Drainage.

Burrill, A. 1997. Assessing the societal value of water in its uses. *Sevilla, Spain: Institute for Prospective Technological Studies, Joint Research Centre of the European Commission.*

Caldas, J. C., P. L. Sousa, and L. S. Pereira. 1997. Need for new approaches in valuing water: Learning from a less successful case. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

CEA (Central Environmental Authority). 1994. *Wirawila-Tissa sanctuary & Yodawewa.* Wetland site report & conservation management plan. Sri Lanka: Central Environmental Authority/Euroconsult, Ministry of Transport, Highways, Environment and Women's Affairs.

CEA. 1993. *Bundala national park.* Wetland site report & conservation management plan. Sri Lanka: Central Environmental Authority/Euroconsult, Ministry of Environment and Parliamentary Affairs.

Chambers, R. 1994. Participatory rural appraisal (PRA): Analysis of experience. *World Development* 22(9):1253-1268.

Cooray, P. G. 1984. *The geology of Sri Lanka (Ceylon).* Colombo: National Museum Publication, Department of Government Printing.

EA1P (Environment Action 1 Project). 1997. *Economic and environment linkages in land use for irrigated versus rainfed farming in the dry zone.* Colombo: Ministry of Forestry and Environment and The World Bank.

Erskine, J. M. 1997. Sustainability measures for natural resources. In *People and participation in sustainable development. Understanding the dynamics of natural resource systems,* eds. G. Shivakoti, G. Varughese, E. Ostrom, A. Shukla, and G. Thapa. Proceedings of an International Conference held at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 17-21 March 1996. Bloomington, Indiana, USA: Workshop in Political Theory and Policy Analysis, Indiana University.

FAO (Food and Agriculture Organization). 1992. *CROPWAT, a computer program for irrigation planning and management.* Irrigation and Drainage Paper 46. Rome, Italy: FAO.

Fereres, E., and F. Cena. 1997. Social benefits and environmental constraints of irrigation in an era of water scarcity. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Gosselink, P., and P. Strosser. 1995. *Participatory rural appraisal for irrigation management research: Lessons from IIMI's experience.* Working Paper No. 38. Colombo, Sri Lanka: International Irrigation Management Institute.

Gosselink, P., and J. Thompson. 1997. *Application of participatory rural appraisal methods of action research on water management.* Short report series on locally managed irrigation No. 18. Colombo, Sri Lanka: International Irrigation Management Institute.

Hoogendam, P. 1995. *Water rights in irrigation management: The property issue.* Unpublished lecture notes, Wageningen Agriculture University.

IIMI (International Irrigation Management Institute). 1990. *Irrigation management and crop diversification.* Volume II, final report on the Technical Assistance Study. Colombo, Sri Lanka: International Irrigation Management Institute.

IIMI. 1995a. *Kirindi Oya Irrigation and Settlement Project. Project Impact Evaluation Study.* Volume II: Annexes (final report). Colombo, Sri Lanka: International Irrigation Management Institute.

IIMI. 1995b. *Irrigation management and crop diversification.* Volume II, final report on the Technical Assistance Study, phase II. Colombo, Sri Lanka: International Irrigation Management Institute.

ILACO (International Land Development Consultants). 1981. *Agricultural compendium for rural development in the tropics and the subtropics.* International Land Development Consultants, Arnhem, The Netherlands: Elsevier Scientific Publishing Company.

Jehangir, W. A., M. Mudasser, Mahmood-ul-Hassan, and Z. Ali. 1998. *Multiple uses of irrigation water in the Hakra 6-R distibutary command area, Punjab, Pakistan.* Report No. R-61. Lahore, Pakistan: International Irrigation Management Institute.

Kloos, H., G. I. Higashi, J. A. Cattani, V. D. Schlinski, N. S. Mansour, and K. D. Murrell. 1983. Water contact behavior and schistosomiasis in an upper Egyptian village. *Social Science and Medicine* 17:545-562.

Konradsen, F., W. van der Hoek, C. Perry, and D. Renault. 1997. Water: Where from, and for whom? *World Health Forum* 18(1):41-43.

Meinzen-Dick, R., and M. W. Rosegrant. 1997. Water as an economic good: Incentives, institutions, and infrastructure. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Meinzen-Dick, R., and M. Zwarteveen. 1998. Gendered participation in water management: Issues and illustrations from water users' associations in South Asia. In *Gender analysis and reform of irrigation management: Concepts, cases and gaps in knowledge.* Proceedings of the international Workshop on Gender and Water. September 1997, eds. D. J. Merrey, and S. Baviskar. Colombo: International Water Management Institute.

Molden, D. 1997. *Accounting for water use and productivity.* SWIM Paper 1. Colombo, Sri Lanka: International Irrigation Management Institute.

Morris, J., E. K. Weatherhead, J. A. L. Dunderdale, C. Green, and S. Tunstall. 1997. The feasibility of tradeable permits for water abstraction in England and Wales. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Munasinghe, M. A. K., and S. Somasiri. 1992. Moisture consumption by dominant vegetation types in the dry zone of Sri Lanka and its influence on the hydrological cycle. *Tropical Agriculturist* 148. Peradeniya, Sri Lanka: Land and Water Management Research Centre.

National Water Supply and Drainage Board (NWS&DB). 1985. *Feasibility study on water supply to new towns & settlement areas under Kirindi Oya project.* Sri Lanka: National Water Supply and Drainage Board.

NWS&DB. 1997a. *National Water Supply and Drainage Board, Notice to all consumers of water.* Sri Lanka: National Water Supply and Drainage Board.

NWS&DB. 1997b. *Water tariff structures.* Colombo, Sri Lanka: National Water Supply and Drainage Board, Ministry of Housing and Construction.

Perry, C. J., M. Rock, and D. Seckler. 1997. *Water as an economic good: A solution, or a problem?* Research Report 14. Colombo, Sri Lanka: International Irrigation Management Institute.

Pigram, J. J. 1997. The value of water in competing uses. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Postle, M. G., N. Berry, and R. Westcott. 1997. The economics of low flow rivers. In *Water: Economics, management and demand*, eds. M. Kay, T. Franks, and L. Smith. London: E & FN Spon.

Pretty, J. N., I. Guijt, I. Scoones, and J. Thompson. 1995. *A trainer's guide for participatory learning and action.* London: International Institute for Environment and Development.

Rasmussen, L. 1994. Comprehensive water resources management. In *Water resources management in Sri Lanka.* Draft strategic framework and action plan, Volume 2: Annexes. Working paper prepared under Technical Assistance Project. TA 1918-SK1, with the Asian Development Bank and USAID.

Reidinger, R. 1994. Observations on water markets for irrigation systems. In *Water policy and water markets: Selected papers and proceedings for the World Bank's ninth annual irrigation and drainage seminar, Annapolis, Maryland: December 8-10, 1992,* eds. G. Le Moigne, K.W. Easter, W.J. Ochs, and S. Giltner. Washington D.C.: The World Bank.

Röling, N. G. 1994. Communication support for sustainable natural resource management. *IDS Bulletin* 25:125-133.

Sakthivadivel, R., D. J. Molden, and C. De Fraiture. Forthcoming. *Water accounting for use and productivity of basin water: Some examples.* Research Report. Colombo, Sri Lanka: International Water Management Institute.

Schlager, E., and E. Ostrom. 1992. Property-rights regimes and natural resources: A conceptual analysis. *Land Economics* 68(3):249-262.

Seckler, D.W. 1966. On the uses and abuses of economic science in evaluating public outdoor recreation. *Land Economics* X L11(4):485-494.

Seckler, D., U. Amarasinghe, D. Molden, R. de Silva, and R. Barker. 1998. *World water demand and supply, 1990-2025: Scenarios and issues.* Research Report 19. Colombo, Sri Lanka: International Water Management Institute.

Stanbury, P. 1989. *Land settlement planning for improved irrigation management: A case study of the Kirindi Oya Irrigation and Settlement Project.* IIMI Country Paper Sri Lanka 4. Colombo, Sri Lanka: International Irrigation Management Institute.

Steele, P., F. Konradsen, and K. A. U. S. Imbulana. 1997. *Irrigation, health, and the environment: A literature review with examples from Sri Lanka.* Discussion Paper No. 42. Colombo, Sri Lanka: International Irrigation Management Institute.

Steins, N. A., and V. M. Edwards. 1998. *Platforms for collective action in multiple-use CPRs.* Paper presented at the 7th Conference of the International Association for the Study of Common Property, June 10-14 1998, Vancouver.

Tanji, K. K. (ed). 1996. *Agricultural salinity assessment and management.* ASCE manuals and reports on engineering practice No.71. New York: American Society of Civil Engineers.

Upasena, J., and P. Abeygunawardena. 1993. Economic value of irrigation water in Dewahuwa irrigation scheme. In *Tropical agricultural research. Vol. 5, 1993:* Proceedings of the 5th Annual Congress of the Post Graduate Institute of Agriculture, 4-5 November 1993, ed, A. A. Jayasekera. Peradeniya, Sri Lanka: Post Graduate Institute of Agriculture.

Whittington, D., and V. Swarna. 1994. *The economic benefits of potable water supply projects to households in developing countries.* Economic Staff Paper No. 53, Manila: The Asian Development Bank.

WHO (World Health Organization). 1993. *Guidelines for drinking water quality. Volume 1: Recommendations.* Second edition. Geneva, Switzerland: WHO.

WHO. 1984. *Guidelines for drinking water quality. Volume 2: Health criteria and other supporting information.* Geneva, Switzerland: WHO.

Yoder, R. 1983. *Non-agricultural uses of irrigation systems: Past experiences and implications for planning and design.* London: Overseas Development Institute.

Young, R. A. 1996. *Measuring economic benefits for water investments and policies.* World Bank Technical Paper No.338. Washington, D.C.: The World Bank.

Zwarteveen, M. 1994. *Gender issues, water issues.* Working Paper No. 32. Colombo, Sri Lanka: International Irrigation Management Institute.

SWIM Papers

1. *Accounting for Water Use and Productivity.* David Molden, 1997.
2. *How to Manage Salinity in Irrigated Lands: A Selective Review with Particular Reference to Irrigation in Developing Countries.* Jacob W. Kijne, S. A. Prathapar, M. C. S. Wopereis, and K. L. Sahrawat, 1998.
3. *Water-Resource and Land-Use Issues.* I. R. Calder, 1998.
4. *Improving Water Utilization from a Catchment Perspective.* Charles Batchelor, Jeremy Cain, Frank Farquharson, and John Roberts, 1998.
5. *Producing More Rice with Less Water from Irrigated Systems.* L. C. Guerra, S. I. Bhuiyan, T. P. Tuong, and R. Barker, 1998.
6. *Modeling Water Resources Management at the Basin Level: Review and Future Directions.* Daene C. McKinney, Ximing Cai, Mark W. Rosegrant, Claudia Ringler, and Christopher A. Scott, 1999.
7. *Water Harvesting and Supplemental Irrigation for Improved Water Use Efficiency in Dry Areas.* Theib Oweis, Ahmed Hachum, and Jacob Kijne, 1999.
8. *Multiple Uses of Water in Irrigated Areas: A Case Study from Sri Lanka.* Margaretha Bakker, Randolph Barker, Ruth Meinzen-Dick, Flemming Konradsen, 1999.

INTERNATIONAL WATER MANAGEMENT INSTITUTE
P O Box 2075 Colombo, Sri Lanka
Tel (94-1) 867404 • Fax (94-1) 866854 • E-mail iwmi@cgiar.org
Internet Home Page http:/ /www.cgiar.org/iwmi

ISBN 92-9090-380-5

ISSN: 1028-6705