51

Research Report

Valuing Water in Irrigated Agriculture and Reservoir Fisheries: A Multiple-Use Irrigation System in Sri Lanka

Mary E. Renwick

International Water Management Institute

Research Reports

IWMI's mission is to improve water and land resources management for food, livelihoods and nature. In serving this mission, IWMI concentrates on the integration of policies, technologies and management systems to achieve workable solutions to real problems– practical, relevant results in the field of irrigation and water and land resources.

The publications in this series cover a wide range of subjects– from computer modeling to experience with water user associations– and vary in content from directly applicable research to more basic studies, on which applied work ultimately depends. Some research reports are narrowly focused, analytical, and detailed empirical studies; others are wide-ranging and synthetic overviews of generic problems.

Although most of the reports are published by IWMI staff and their collaborators, we welcome contributions from others. Each report is reviewed internally by IWMI's own staff and Fellows, and by external reviewers. The reports are published and distributed both in hard copy and electronically (www.iwmi.org) and where possible all data and analyses will be available as separate downloadable files. Reports may be

Research Report 51

Valuing Water in Irrigated Agriculture and Reservoir Fisheries: A Multiple-Use Irrigation System in Sri Lanka

Mary E. Renwick

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

IWMI receives its principal funding from 58 governments, private foundations, and international and regional organizations known as the Consultative Group on International Agricultural Research (CGIAR). Support is also given by the Governments of Pakistan, South Africa, and Sri Lanka.

The author: Mary E. Renwick is Economist at Water Resources Center, University of Minnesota.

The author specially thanks David Molden, Margaretha Bakker, Parakrama Weligamage, David Seckler, R. Sakthivadivel, Manju Hemakumara, and Daniel Renault of the International Water Management Institute and the anonymous reviewers for their invaluable insights, comments, suggestions and assistance.

M. E. Renwick. 2001. *Valuing water in irrigated agriculture and reservoir fisheries: A multiple-use irrigation system in Sri Lanka*. Research Report 51. Colombo, Sri Lanka: International Water Management Institute.

/ irrigation management / water management / water use efficiency / water allocation / domestic water / water quality / irrigated farming / paddy / fisheries / reservoirs / productivity / agricultural production / irrigation systems / Sri Lanka / Kirindi Oya /

ISBN: 92-9090-439-9

ISSN 1026-0862

Please direct inquiries and comments to: *iwmi-research-news@cgiar.org*

Contents

Abstract

Although irrigation projects often provide water for more than crop irrigation, water allocation and management decisions often do not account for nonirrigation uses of water. Failure to account for the multiple uses of irrigation water may result in inefficient and inequitable water allocation decisions. Decision-makers often lack information on the relative economic contributions of water in irrigation and nonirrigation uses. This report addresses this problem. It examines the relative economic contributions of irrigated agriculture and reservoir fisheries in the Kirindi Oya irrigation system, located in southeastern Sri Lanka. The results of the analysis indicate the importance of both irrigated paddy production and reservoir fisheries to the local economy. They also demonstrate significant potential financial and economic gains to irrigated agriculture from improvements in water management practices. Since these water uses are interdependent, policy makers must consider how changes in water management practices may affect reservoir levels and water quality and the fisheries that depend on them.

Valuing Water in Irrigated Agriculture and Reservoir Fisheries: A Multiple-Use Irrigation System in Sri Lanka

Mary E. Renwick

Introduction

Irrigation water supply projects often provide water for more than just crop irrigation. Water is used for domestic purposes, fisheries, and livestock, as well as for wildlife habitat, and environmental preservation and enhancement. The importance of nonagricultural uses of water in relation to the economic development and quality of life for the rural poor in developing countries has often been ignored. Failure to recognize the nonagricultural uses of water has important implications for irrigation project management, water rights, and the economic appraisal of the irrigation projects themselves.

As competition for available water resources continues to increase in the twenty-first century, policy makers and water managers must, more than ever, rely on improvements in management to meet the demands of competing users. The main problem is that water resource managers and decision makers lack the information that would allow them to assess the potential trade-offs among different user groups. Improving the understanding of the potential trade-offs is crucial to the design and implementation of effective management strategies. Knowing the value of water in each of its alternative uses is essential for the decision-making process and it improves the efficiency with which water supplies are managed and allocated among competing users.

The Kirindi Oya Irrigation and Settlement Project (KOISP) in Sri Lanka provides an excellent opportunity to examine the potential gains brought to agriculture and reservoir fisheries by improving the management of irrigation water. The KOISP has performed significantly below expected levels. Concerted efforts are underway to improve system performance. New management strategies will incur changes in how water is issued throughout the system. As irrigation water is used for crop production, as well as for fisheries, domestic purposes, livestock, and is vital for the environment, it is important to examine how changes in the water management regime may affect all uses.

The total economic valuation (TEV) framework provides a systematic approach for assessing the combined economic values of all the goods and services produced by a resource-based system (Pearce 1993; Randall 1991). As noted by the National Research Council (NRC) (1996), “In the same way that physical resource functions are interconnected, economic values for the various goods and services produced are interconnected … A valid TEV measurement must account for this interconnectedness … while the concept of TEV is generally accepted by economists, systematic attempts to measure TEV in a regional policy or planning context are rare.”

Many valuation taxonomies (Winpenny 1991; Munasinghe 1992; Pearce 1993; Freeman 1993; and Dixon et al. 1994) have been developed to categorize the types of economic values associated with water and other natural resources within the TEV framework (NRC 1996). Representative taxonomies that reflect the economic channels through which a resource's service is valued include use and nonuse values. The use values are determined by the contribution of a resource to the production or consumption of a good or service; the nonuse values are non-marketed goods and services having *intrinsic* properties such as option, bequest or existence values (NRC 1996).[1] *Non-marketed* goods refer to goods and services neither priced nor traded in markets. The ability to assign a value to non-marketed goods and services has improved the accuracy of cost-benefit analysis. Thus, assessments reflect the consequences of natural resource policies and regulations more fully.

Specialized techniques have been developed to assess the value of non-marketed goods and services in a manner commensurate with assessment of more conventionally marketed commodities. The valuation taxonomy and concomitant valuation techniques employed should be structured to reflect specific attributes of a resource's values or benefits (Freeman 1993). Over the past 30 years a variety of techniques, ranging from relatively simplistic to highly theoretical, have been developed to assess the value of non-marketed goods and services. According to Dixon (1991), "… the more useful approaches for valuing environmental effects, especially of projects, have frequently been the simplest … The more experimental techniques, or those that require extensive data sets … have had much more limited applications to date. In developing countries the most useful approaches have been those that require the fewest assumptions and the least amount of data."

This report is based on a previous work done on the KOISP (Bakker et al. 1999; Meinzen-Dick and Bakker 1999) that identified and described the full range of water-related goods and services. The water-related goods and services that were identified included use of water for paddy irrigation, field crop production, reservoir fisheries, livestock watering, domestic bathing, clothes laundering, and cottage industries such as curd production, clay pot and brick manufacturing, and shell mining. This previous study described the importance of each water use. However, only cursory estimates of certain water uses were made. For example, only approximate estimates of the gross value of paddy production were calculated.

This report takes the first step in the TEV approach by focusing on economic valuation of two important uses of KOISP water–irrigated paddy production and reservoir fisheries. A primary justification for the development of the KOISP was to expand irrigated paddy land. Despite its importance, the economic value of water in irrigated paddy production had not been measured. The value of water for irrigated paddy production can be used to measure the potential gains and losses to irrigated paddy obtained by adopting alternative management strategies.

The study of fisheries was chosen for a number of reasons. First, although fisheries contribute substantially to the local economy, their contribution has never been formally investigated. Second, new management strategies would probably reduce the quantity and quality of water, in the reservoirs where the fisheries are located, thus affecting the fisheries' productivity.[2] Third, a significant number of

[1]Option values refer to the value individuals place on the potential future use of a resource, such as willingness to pay today for the option to exercise further water rights. Bequest values refer to the present generations' desire to bequest the resource for future generations. Existence values reflect contemplative values for the mere existence of a resource.

[2]Previous research by Amarasinghe (1987) and De Silva (1985) indicates a correlation between fisheries' productivity and reservoir levels. The exact nature of this relationship is not well understood.

benefits for the rural poor and for wildlife have been associated with the Sri Lankan inland fisheries. Fisheries provide a source of inexpensive protein for the rural poor. They also provide some degree of malaria control, as the fish feed on mosquito larva and floating algae, a nesting medium for mosquitoes. Fisheries also help maintain the piscine predatory bird population that feeds on juvenile fish.[3]

This report is organized as follows. The following section describes the KOISP and its water users, focusing on the characteristics of water resource availability for irrigated crop production and fisheries habitat. Next, the measures of the financial returns to irrigated paddy production and the value of water in paddy production under current and targeted irrigation intensities are dealt with. An economic assessment of the inland fisheries and measures of the financial and economic returns to reservoir fisheries are provided. Finally, the conclusions, policy and management implications, and future research needs are discussed.

Kirindi Oya Irrigation and Settlement Project (KOISP)

The KOISP is located in the southeast dry zone of Sri Lanka, about 260 km from Colombo (figure 1). It includes an ancient reservoir-based irrigation system with five small reservoirs, known as the Ellegala system, built by King Mahanaga over 1,000 years ago during the Ruhuna Civilization (Sri Lanka Department of National Planning 1992). Prior to the construction of the Lunugamwehera reservoir in 1987, inflow to the ancient reservoirs came from a Kirindi Oya River diversion and rainfall runoff from within their own catchment areas.

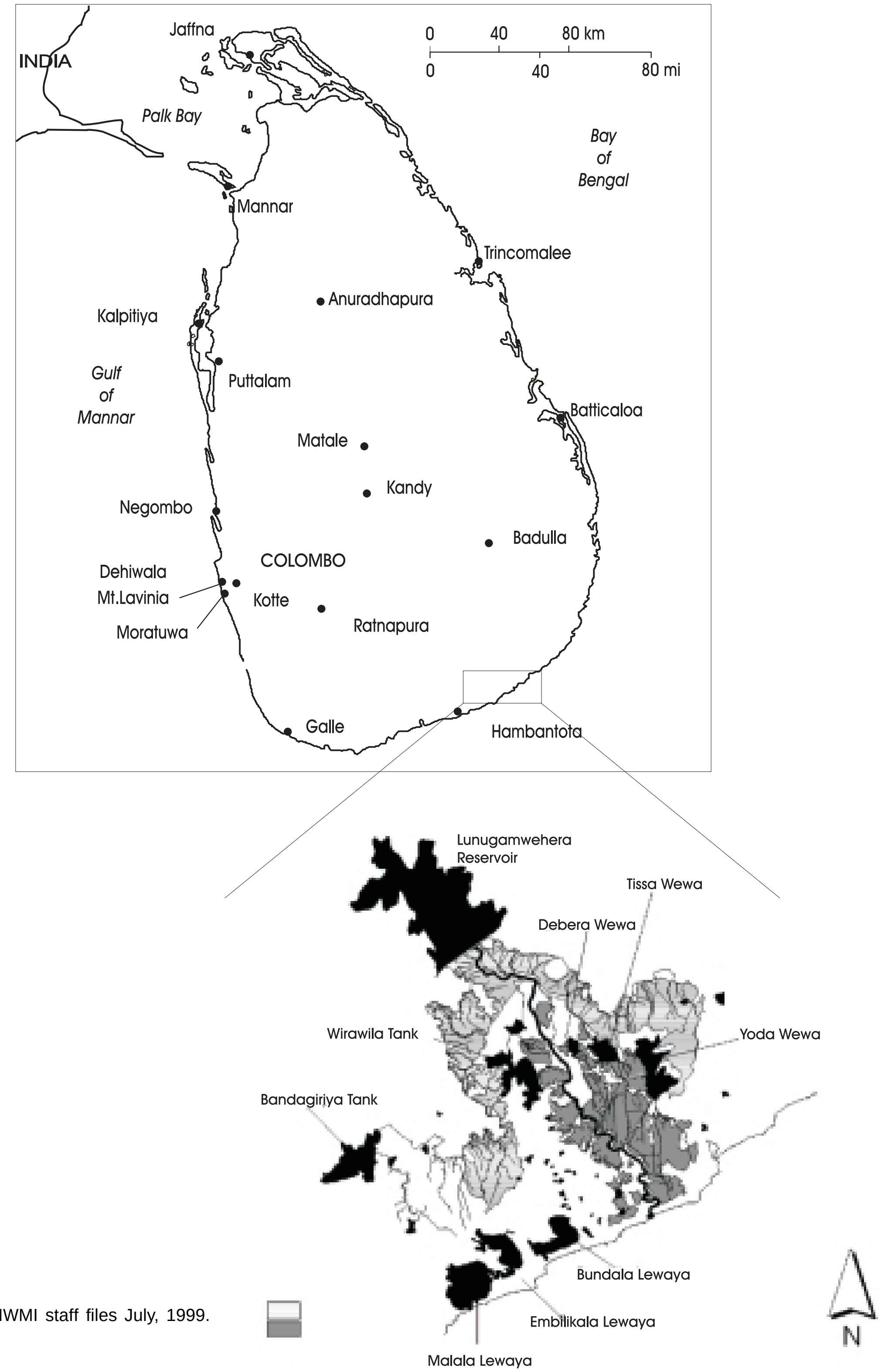
During the mid-1980s, the old Ellegala system was rehabilitated and incorporated into the KOISP, an open cascade irrigation system that ultimately drains into the Indian Ocean. This new irrigation scheme entailed the construction of a headwaters reservoir–Lunugamwehera–to provide irrigation facilities for 5,400 hectares of new lands (New Area) and supplementary water for 4,200 hectares of existing lands serviced by the old Ellegala system (Old Area). The New Area is situated in the highlands around the Old Area lands, with Lunugamwehera located at the apex (figure 1). The New Area lands were allotted to families displaced by the construction of the KOISP and to landless families from other parts of the country.

The New Area lands receive water directly from Lunugamwehera through a canal system. The Old Area lands receive irrigation water from the five ancient reservoirs located in the Old Area: Debera Wewa, Tissa Wewa, Yoda Wewa, Pannegamuwa, and Wirawila (Marikar 1999). These reservoirs receive about 30 percent of their inflow directly from the Lunugamwehera reservoir. Return drainage flows from the New Area and rainfall runoff constitute the remaining 70 percent of inflows to the ancient reservoirs. The exact proportion of return flows from the New Area to the Old Area reservoirs is not precisely known but is estimated to be more than half the total inflow (IWMI 1995).[4]

[3]In Sri Lanka's Parakrama Samudra reservoir, Winkler (1983) found that daily predation by birds of juvenile *O. mossambicus* (the primary inland fisheries' species) almost equaled the daily yield of the commercial inland as measured by weight.

[4]After the construction of the new Lunugamwehera reservoir, the Left and the Right Bank main canals of the new reservoir cut through the natural catchments of the old tanks under the Ellegala system. Thus the areas south of the Left Bank of the reservoir (tracts 1 and 2) drain into Debera Wewa, Tissa Wewa, and Yoda Wewa. The areas east of the Right Bank canal (tracts 1 and 2) drain into the Wirawila and Pannegamuwa Wewa. The areas south of the Right Bank canal (tracts 5, 6 and 7) drain into the Embilikala and Malala lagoons through the Weligatta area and into several other outflows to the ocean that cut across the road leading to Tissamaharama from Hambantota (IWMI 1995).

FIGURE 1.
An overview of the KOISP area.



Source:IWMI staff files July, 1999.

The KOISP was originally designed to provide adequate water to ensure an irrigation intensity of 200 percent (two crops per year) over 9,600 hectares of land. The KOISP has not met the initial irrigation expectations, which were expansion of cultivation area and increase of cropping intensities. Data on actual performance during the 1989–97 period indicate an irrigation intensity of 134 percent over the entire command area for paddy production,[5] or 157 percent including other field crops (OFCs). Paddy irrigation intensities in the Old and the New Areas were 179 percent and 100 percent, respectively (Marikar 1999), which means that New Area producers have only been able to grow, on average, one irrigated paddy crop per year.

The New Area cultivators regularly encounter significant reductions in their water supply because, in the design and implementation of the KOISP, the Central Government recognized the seniority of existing water rights in the Old Area. With only one crop per year, most New Area settlers have been unable to establish permanent year-round homesteads for their families. A large proportion of the New Area farmers reside in the Kirindi Oya area only during the maha (wet) season from October to February and migrate back to their native villages during the yala (dry) season from April to August, due to lack of available water supplies. As a result, agricultural productivity has remained very low and the local agriculture-dependent economy has failed to grow as anticipated.

A number of factors accounting for the poor performance include errors in the planning and assessment of water resources, the existence of cropping patterns other than those assumed in the project design, and high water delivery requirements (duties) (Nijman 1992). The actual water availability is 25–60 percent less than anticipated at the time of planning and design (Dharmasena 1988; Nijman 1992). The initial estimates of runoff flowing into Lunugamwehera ranged from 298 to 347 million cubic meters (MCM) per annum. The actual runoff has been significantly less, averaging 207 MCM over the 1986–96 period (Renault 1997). During the planning and design phase of the KOISP it was assumed that, in the New Area, OFCs, rather than paddy, would be produced in significantly higher proportions. However, agricultural producers prefer to cultivate paddy, which requires heavier water duties than OFCs, particularly in the relatively well-drained soils of the New Area.[6] Over the 1989–97 period, paddy constituted approximately 86 percent of the total cultivated area.

The current performance of the system, as measured by process fraction (Molden 1997), is 28 percent (Renault 1997).[7, 8] Meeting the targeted irrigation intensity of 200 percent on 9,600 hectares of land, with current water resources, will require an increase in system performance of 40–44 percent.[9] According to Renault (1997) this is an achievable level of system performance, essentially requiring improvements in management using existing infrastructure.

[5]This estimate is based on 1989–97 average annual irrigated paddy area of 12,904 hectares plus 2,121 hectares of OFCs on 9,600 hectares of land over the maha and yala growing seasons (Marikar 1999).

[6]The soils in the New Area are a mixture of 75% well-drained Reddish Brown earth (*Chromic Luvisols LVx*), in the upper reaches, and 25% of Solodized Solonetz (*Gleyic Solonetz Sng*) in the lower reaches. Thus, soils in the New Area are more suited for non-paddy crops. The soils in the Old Area are a mixture of 30% Alluvial soils, 40% Reddish Brown Earth (RBE), 10% Regosols and 20% Low Humic Gley (LHG) soils and are equally suited for paddy and other crops.

[7]Process fraction is defined as the percentage ratio of paddy evapotranspiration divided by water resources (reservoir inflow plus rainfall). Evapotranspiration provides a measure of consumptive use.

[8]Estimate based on evapotranspiration for 6,600 hectares of cultivated paddy land of 112 MCM per year and water resources availability of 400 MCM (inflow to Lunugamwehera of 207 MCM and rainfall of 193 MCM).

[9]Estimate based on evapotranspiration for 9,600 hectares of 163 MCM per year divided by annual available water resources of 400 MCM.

Water recycling is a key component of the management approach. The Kirindi Oya system is an open cascade system, which drains into the Indian Ocean. According to van Eijk, Molden and Sakthivadivel (1999), approximately 35 percent of all inflows to the system drain into the ocean without being reused. Clearly, opportunities for improvements in efficiency exist. For example, based on drainage flow measurements, drainage from the Right Bank in the New Area appears sufficient to irrigate an additional 500 hectares of land (Hemakumara 1999).

Concerted effort is underway in the Kirindi Oya area to realize the 200 percent irrigation intensity target. To achieve this goal, the Irrigation Department and producers are relying on two management techniques:

- Recycling of drainage water by creating anicuts (figure 2).

- Modification of the water issuance plan by implementing a rotating wet and dry supply schedule consisting of 3 days on and 4 days off.

On the whole, it appears that a dynamic process is underway in Kirindi Oya. There is a significant increase of dialogue between farmers and the Irrigation Department, and the confidence in their working relationship is growing (Renault 1999). As alternative management strategies are being considered for the coming seasons, it will become increasingly important for the Irrigation Department and the

FIGURE 2.
The anicut built in 1999.

Source: Daniel Renault, IWMI, July 1999.

producers to take into account the potential trade-offs among different types of water uses, obtained under alternative management strategies. Economic valuation provides one framework for analyzing the potential trade-offs associated with alternative management scenarios.

Economic Value of Water for Irrigated Paddy Production

Agriculture plays a substantial role in the local economy of the Kirindi Oya area. It accounts for about 55 percent of the household income in both the New and the Old Areas and for more than 75 percent of all employment (IWMI 1995). Paddy cultivation is the largest single source of agricultural income, accounting for 27 percent of the total household income in the New Area and 33 percent in the Old Area. The Old Area economy is more urbanized, as many settlements have been established for centuries. The 1994 average household income in the Old Area was about Rs 66,800 (US$954),[10] almost twice as high as that of the New Area (Rs 36,100 or US$515), reflecting higher levels of irrigation intensity and resource endowment, and a more diversified economic base in the Old Area (IWMI 1995). Beyond crop production, the New Area households earn a significant share of their agricultural income by hiring themselves out as agricultural laborers. In contrast, the Old Area households earn a larger share of agricultural income by leasing their agricultural implements such as tractors (IWMI 1995).

Agricultural production is dominated by paddy cultivation. Given adequate water supplies, agricultural producers will cultivate rice in both maha and yala. The majority of producers use new improved varieties of paddy seed. Two-wheel tractors are used for land preparation, predominately on a contract basis.[11] Most rice is broadcast due to the high labor costs of transplanting. In general, farmers apply the recommended quantities of fertilizers but the tendency to overapply nitrogen at the expense of other elements has been observed by IWMI field staff. Field observation also reveals a tendency to apply pesticides and herbicides in excess of requirements, as farmers fear crop loss. A significant share of labor-related activities is done on a contract basis, where the landowner pays a group of individuals to perform some service. The majority of producers lease equipment such as pesticide applicators and threshing machines.

The Old Area producers hold senior water-use rights and thus receive priority in water allocations. Table 1 shows total irrigable hectares and the area actually cultivated during the 1989–97 period.[12] A comparison of the Old and the New Areas clearly illustrates the relationship between priority in water-use rights and area under cultivation. In the Old Area, 97 percent of irrigable land was cultivated in maha and 81 percent in yala. In the New Area, 68 percent of the irrigable area was cultivated in maha and 29 percent in yala. Reliability and timing of water supplies also vary. An analysis of actual water allocations by season over the 1989–97 period revealed that, while the Old Area lands received water in all seasons during the period,

[10]The exchange rate used throughout is US$1.00=Rs 70.

[11] A small percentage of farmers use four-wheel tractors.

[12]Targeted allocations are from, Brewer (forthcoming) and can be found in Bakker et al. (1999).

TABLE 1.
Total irrigable area and average cultivated area for KOISP, 1989–997.[a]

Irrigable land/Area cultivated	Maha	Yala	Total
Total KOISP irrigable land (ha)	9,600	9,600	19,200
Paddy	7,795	5,109	12,904
OFCs	1,240	881	2,121
Cultivated (%)	94	62	78
Irrigation intensity (paddy) (%)[b]	-	-	134
Old Area irrigable land (ha)	4,200	4,200	8,400
Paddy (ha)	4,092	3,412	7,504
Cultivated (%)	97	81	89
Irrigation intensity (%)			179
New area irrigable land (ha)	5,400	5,400	10,800
Paddy (ha)	3,703	1,694	5,397
Cultivated (%)	68	29	49
Irrigation intensity (%)	-	-	100

Sources: Irrigation Department, Department of Agriculture, Irrigation Management Division and Agrarian Services Centers as reported in van Eijk et al. (1999).

[a]Targets based on allocation rules identified by Brewer (1999) as shown in Bakker et al. (1999). Irrigable lands in the New Area that did not receive water for maha have priority for yala.

[b]Including OFCs, the average irrigation intensity is 157%.

the New Area lands received water only, on average, in six out of eight maha seasons and in only two out of eight yala seasons (table 2). Even when specific areas received irrigation water, the quantity, reliability, and timing of supplies often varied depending on whether a producer's land was located near the head or tail end of the delivery subsystem.

To better understand the potential financial and economic gains obtained from improvements in system performance, a producer-level profit maximization model is utilized to estimate the value of water in paddy cultivation under current and targeted cropping intensities. From a production theory perspective, irrigation water is an intermediate good–an input used to produce a final product. The value of an intermediate good is defined as the net economic contribution of that good to the value of the final output. The residual method, based on a producer-level profit maximization model, is used to calculate the value of irrigation water in irrigated paddy production. Appendix A details the generalized theoretical model. The residual approach entails identification of the incremental contribution of each input to the value of the total output.[13] It is the most widely used methodology for valuing irrigation water (Young 1996). Under this approach, all costs of production, except water,

[13]Eulers' theorem, upon which the residual method is based, provides the theoretical basis for identification of the incremental contribution of each input to the value of total output. The generalized theoretical model presented in appendix A assumes a homogeneous technology structure, also referred to as constant returns to scale (CRS). In the context of irrigated paddy production, the CRS assumption implies that correspondence between inputs and outputs remains constant, for the observed input and output levels (e.g., a 20% increase in inputs increases outputs by 20%). Eulers' theorem can also be generalized to hold for nonhomogeneous technology structures (Chiang 1984). This requires zero long-run profits or zero industry profits, even if individual producers are realizing non-zero profits in the short run, which can be established under free exit and entry into the industry.

TABLE 2.
Number of seasons water is allocated to command areas, 1989–97.

Area	Maha (8 seasons)	Yala (8 seasons)	Total (16 seasons)
Old Area[a]	8	8	16
New Area			
Left Bank			
Tract 1	7	3	10
Tract 2	7	2	9
Tract 3	3	1	4
Average	5.7	2.0	7.7
Right Bank			
Tract 1	7	3	10
Tract 2	6	3	9
Tract 5	7	2	9
Tract 6&7	5	2	7
Average	6.3	2.5	8.8

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

[a]All subsystems within the Old Area received irrigation water in all seasons. These include: Tissa Wewa, Yoda Wewa, Wirawila, Pannegamuwa, and Debera Wewa.

are subtracted from the value of production. This remaining (or residual) value provides an estimate of the value of irrigation. Proper implementation of the residual methodology requires that special care is taken to ensure all cash and noncash costs of production are adequately captured.

The analysis, conducted for this paper, relies on detailed farm-level cost of production surveys conducted in the Kirindi Oya command areas for the maha 1998–99 season. A stratified random sample of 84 agricultural producers was selected from 10 subsystems within the Old and the New Areas.[14]

Table 3 shows adjusted yields, cultivated area, and farm gate prices received for irrigated paddy during maha 1999. The average adjusted yield for the area was 4,728 kilograms per hectare.[15] Yields, in the Old Area, were slightly higher and more variable than in the New Area. The Old Area farmers cultivated 1.26 hectares of irrigated paddy land on average. The New Area farmers cultivated 1.03 hectares of land on average, reflecting their KOISP allotment of one hectare of cultivable land per household. The average farm gate price received for paddy was Rs 13.86 (US$0.2) per kilogram and ranged from Rs 13.36 on the New Area Left Bank to Rs 14.07 in the Old Area.

Table 4 shows the average per-hectare input levels and concomitant costs for maha 1999 for the KOISP command area. The average

[14]The Old Area command areas include Wirawila, Yoda Wewa, Tissa Wewa, Pannegamuwa, and Debera Wewa. The New Area command areas include Left Bank tracts 1, 2 and 3 and Right Bank tracts 1 and 2. Data on cost of production for Right Bank tracts 5, 6 and 7 were collected in early 1999 on a nearly identical survey for yala 1998. However, sufficient differences in the calculation of economic returns exist to prevent its inclusion in the current analysis.

[15]For details on adjusted yields, see appendix C.

TABLE 3.
Adjusted yields, cultivated area and prices received for paddy, Maha 1999.[a]

	Old Area		New Area				Average	
			Right Bank		Left Bank			
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Adjusted yield (kg/ha)	4,796	(579)	4,596	(517)	4,688	(476)	4,728	(547)
Area cultivated in paddy (ha)	1.26	(0.44)	1.06	(0.25)	1.00	(0)	1.17	(0.38)
Farm gate price received (Rs/kg)	14.07	(0.54)	13.69	(0.57)	13.36	(0.51)	13.86	(0.60)

S*ource*: Primary survey data collected in KOISP July 1999.

[a]Standard deviations (s.d.) are shown in parantheses.

economic costs of production for paddy totaled Rs 48,752 (US$696) per hectare. In estimating the economic costs, particular attention was given to estimating *all* input costs including noncash costs such as land, family labor, returns to management, and depreciation for machinery and equipment. Returns to management account for the value of the managerial know-how of the producer and is set at five percent of the value of gross output. This rate is considered relatively standard for field crops (Young 1996). Appendix B details the assumptions made in calculating noncash costs.

Labor constitutes the largest cost component (35%) followed by materials (23%), land (20%), and machinery (14%). Production costs exhibit substantial variability, as indicated by the standard errors, particularly in labor and material costs for pesticide and herbicide application. A comparison of the Old Area and the New Area operations revealed that the New Area farmers, particularly those located on the Right Bank, tend to spend more on pesticides and herbicides than the Old Area farmers. As the New Area farmers produce on average only one crop per year, they cannot risk losing it and so apply more chemicals. Differences in expenditures on chemicals may also correspond to differences in water availability. When fields are flooded, weed levels are low and herbicides are unnecessary. Conversely, during periods of reduced water availability more herbicides are needed to keep weed levels low.

Table 5 shows the value of output, costs of production, financial returns to irrigated paddy production and the economic returns to water, on a per-hectare basis, for the Old and the New Areas. Financial returns provide a measure of the net financial profitability of irrigated paddy production in the Kirindi Oya area. Economic returns to water measure the contribution of water, as a production input, to the total value of the output. Economic returns provide a measure of the value of water in its current use.

The financial returns to irrigated paddy production average approximately Rs 22,053 (US$315) per hectare, ranging from Rs 21,272 (US$304) in the Old Area to Rs 23,920 (US$342) on the Right Bank of the New Area. Financial returns equal the value of marketed output less cash costs of production. The average value of marketed production was about Rs 55,400 (US$791) per hectare. Total costs of production averages are relatively similar across all areas. However, they are significantly more variable in the Old Area, in relation to the New Area, as a result of greater variability in labor and machinery costs in the Old Area. These results reflect greater differences between the Old Area farmers with respect to labor and machinery input levels.

Economic returns to water measure the value of water in its current use. They equal the total value of marketed and nonmarketed production less all cash and noncash

TABLE 4.

Per-hectare inputs and costs for the KOISP command area, maha 1999.[a]

Input	Quantity		Cost (Rs)	
	Mean	s.d.	Mean	s.d.
Land (ha)[b]	1		10,328	(1,512)
Materials (kg)				
Seed	224.6	(29.7)	3,523	(471)
Fertilizer	430.1	(87.6)	4,551	(1,071)
Pesticides/herbicides[c]	-	-	3,292	(939)
Subtotal	-	-	11,366	(1,835)
Labor (days)[d]				
Land preparation	15.5	(3.6)	3,098	(733)
Planting[e]	9.1	(1.9)	1,818	(390)
Irrigation	19.0	(4.9)	952	(245)
Fertilizer application	3.7	(0.9)	736	(187)
Pesticide/herbicide application	4.0	(0.9)	1,192	(283)
Harvest-related	42.7	(6.0)	7,953	(1,208)
Subtotal[f]	94	(14.9)	15,749	(2,409)
Machinery (days)				
2-wheel tractor	2.7	(0.9)	4,328	(1,737)
4-wheel tractor	0.2	(0.7)	308	(1,211)
Chemical applicators	3.6	(1.3)	262	(191)
Threshing machine	1.8	(0.4)	2,320	(764)
Subtotal	8.3	(1.7)	7,218	(1,445)
Operating interest (Rs/ha)	-	-	815	(120)
Returns to management (Rs/ha)	-	-	3,275	(395)
Total costs (Rs/ha)	-	-	48,752	(4,443)

Source: Primary survey data collected in KOISP July 1999.

[a]Standard deviations (s.d.) are shown in parentheses.

[b]For unreported lease values, the mode lease value of irrigated land at Rs 12,500 per hectare was used for the Old Area lands. For the New Area producers, who received land allotments from the central government a lease value for irrigated land of Rs 10,000 per hectare was used, to reflect differences in water supply availability.

[c]Due to the varying types of pesticides and quantities used (liquid and dry form) the average quantity of pesticide input could not be measured.

[d]For family labor, the observed modal values for contract labor were used (see appendix B for details). For irrigation labor days, the average contract rate of Rs 200 per day was prorated based on two hours per reported irrigation labor day. Most irrigation labor in Kirindi Oya involves opening and closing the canal gates, which requires approximately 2 hours.

[e]The reported number of labor days for this activity includes final leveling of the field done by contracted labor.

[f]The average total labor costs do not exactly match the sum of average labor costs by activity due to differences in labor practices among producers. The cost estimates for machinery include both cash outlays for contracted work and depreciation, and operation and maintenance costs to owners.

TABLE 5.
Per-hectare financial returns to irrigated paddy production and economic returns to water, maha 1999.[a]

	Old Area		New Area				Average	
			Right Bank		Left Bank			
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Yield (kg/ha)	4,796	(579)	4,596	(517)	4,688	(476)	4,728	(547)
Value of production (Rs/ha)[b]								
Marketed	56,648	(7,139)	54,405	(7,542)	52,688	(7,810)	55,425	(7,400)
Home consumption	10,766	(3,668)	8,495	(1,697)	9,985	(2,108)	10,075	(3,172)
Subtotal	67,414	(7,870)	62,900	(7,521)	62,673	(7,175)	65,501	(7,896)
Cost of production (Rs/ha)								
Land	10,560	(1,955)	10,000	(0)	10,000	(0)	10,328	(1,512)
Material	11,301	(2,023)	11,496	(1,658)	11,403	(1,498)	11,366	(1,835)
Labor	15,119	(2,934)	16,608	(968)	16,680	(498)	15,750	(2,409)
Machinery	7,575	(1,788)	6,648	(381)	6,814	(378)	7,218	(1,445)
Operating interest	792	(145)	841	(66)	859	(57)	815	(120)
Subtotal	48,718	(5,555)	48,739	(2,475)	48,890	(1,710)	48,752	(4,443)
Returns to management (Rs/ha)	3,371	(394)	3,145	(376)	3,134	(359)	3,275	(395)
Financial returns to paddy[c]								
(Rs/ha)	21,272	(10,420)	23,920	(7,361)	22,037	(7,161)	22,053	(9,204)
(US$/ha)	304	-	342	-	315	-	315	-
Economic returns to water[d]								
(Rs/ha)	18,696	(8,245)	14,162	(6,534)	13,783	(6,509)	16,748	(7,833)
(US$/ha)	267	-	202	-	197	-	239	-

Source: Primary survey data collected in KOISP in July 1999.

[a]Standard deviations (s.d.) are shown in parentheses.

[b]Average farm gate price received per kilogram by area is as follows: total area Rs 13.86 (s.d. =0.60); Old Area Rs 14.07 (s.d. = 0.54); New Area Left Bank Rs 13.36 (s.d. = 0.51) and New Area Right Bank Rs 13.69 (s.d. = 0.57).

[c]Financial returns to paddy production equal the value of marketed output less cash operating costs. See appendix B for details regarding calculations and definitions of costs.

[d]Economic returns equal the value of production (marketed and home consumed output) less cash and noncash production costs. See appendix B for details regarding calculations and definitions of costs.

production costs. The average per-hectare economic return to water, or value of water, is Rs 16,748 (US$239) and ranges from Rs 13,783 (US$197) on the Left Bank portion of the New Area to Rs 18,696 (US$267) in the Old Area.[16] The greater variability of economic returns to water in the Old Area, as compared to the New Area, stems primarily from variability of labor and machinery costs in the Old Area.

Table 6 shows the per-unit value of water in irrigated paddy production based on the following three alternative means of measurement:

[16]This is a conservative estimate of the economic returns to water, as it includes an average imputed land rent, which may capture some of the value of irrigation. When imputed land rents are excluded, the average economic return to water for a hectare of paddy production in KOISP increases to Rs 27,076 (US$387) per hectare. When imputed land rents are set at 50% of the rates shown in table 4, the average economic return to water for a hectare of paddy production in KOISP is Rs 21,912 (US$313) per hectare.

TABLE 6.
Economic returns to water in paddy production on a per-hectare and per-cubic meter basis.

Economic returns	Old Area	New Area	Total
Per hectare (Rs/ha)	18,696	13,973	16,748
(US$/ha)	267	200	239
Per cubic meter of water:			
Delivered (Rs/m^3)	1.41	0.62	0.93
Consumed (Rs/m^3)	22.50	16.81	20.15
Depleted (Rs/m^3)	1.89	2.31	2.31

Sources: See table 5 for per-hectare economic returns and appendix B for background details on calculations.

- *Water delivery* measures the economic returns per cubic meter of water based on actual water deliveries;

- *Consumptive use* (evapotranspiration) measures the economic returns per cubic meter of water consumed by the crop based on evapotranspiration;

- *Depletive use* measures the economic returns per cubic meter of water consumed and lost through drainage outflows to the ocean.

Economic returns measured per unit of water delivered over the whole Kirindi Oya area average Rs 0.93/m^3. However, economic returns per unit of delivered water in the New Area (Rs 0.62/m^3) are more than doubled in the Old Area (Rs 1.41/m^3). This difference reflects higher water delivery requirements needed to meet the irrigation demands of the relatively well-drained soils of the New Area. This indicates that efficiency improvements could be achieved by reallocating water from the New Area to the Old Area to achieve higher per-unit returns.

When analyzing the consumptive use of water–taking only crop requirements into consideration–the difference between the value of water in the Old and the New Areas decreases substantially. The average economic returns per cubic meter of water consumed for crop production in the Old and the New Areas are Rs 22.50/m^3 and Rs 16.81/m^3, respectively. These results demonstrate that the way in which water is measured influences the estimates of the economic value of water. They also indicate that measuring the value of water based on either deliveries or consumptive use may lead to biased estimates of the true value of water in irrigated paddy production. Water delivery measurements do not include return flows that may be reused downstream, resulting in a downward bias in the estimated value of water. Consumptive use measurements do not include system losses and thus lead to an overestimation of the value of water in its current uses.

Economic returns measured per unit of depleted water appear to provide a better measure of performance of water in its current use. Economic returns per cubic meter of water depleted in the Kirindi Oya area average Rs 1.89 in the Old Area and Rs 2.31 in the New Area (table 6). This measurement incorporates actual crop consumption, reuse of return flows, and system losses in the form of drainage outflows to the ocean. It also serves as a performance benchmark of system-wide allocation efficiency by accounting for changes in efficiency through recycling of water and system losses.

Table 7 shows the total financial returns to paddy production and the economic returns to water for the Kirindi Oya Project area at current and projected levels of irrigation intensity. Total financial returns currently equal Rs 284 million (US$4 million). Economic returns to water in irrigated paddy production currently equal Rs 216 million (US$3.1 million). If improvements in the management of water increased irrigation intensity so that the same amount of water could be used to grow more crops, significant financial and

TABLE 7.
Total value of water in irrigated paddy production under historic and potential cropping.

	Per hectare[a]	1989–97 average[b]	Scenario 1 Old Area = 200% New Area = 150%[c]	Scenario 2 Old Area = 200% New Area = 200%[d]
Old Area				
Irrigated paddy (ha)		7,504	8,400	8,400
Financial returns to paddy			..........(1,000s)..........	
	Rupees ('000)	21,272	159,625	178,685
178,685	US$ ('000)	304	2,281	2,554
2,554				
Economic returns to water				
Rupees ('000)	18,696	140,295	157,046	157,046
US$ ('000)	267	2,004	2,243	2,243
New Area				
Irrigated paddy (ha)		5,397	5,940	8,640
Financial returns to paddy[e]			..........(1,000s)..........	
Rupees ('000)	22,979	124,018	136,495	198,539
US$ ('000)	329	1,776	1,954	2,843
Economic returns to water[e]				
Rupees ('000)	13,973	75,412	83,000	120,727
US$ ('000)	200	1,079	1,188	1,728
Total Area				
Irrigated paddy (ha)		12,904	14,340	17,040
Financial returns to paddy			..........(1,000s)..........	
Rupees ('000)	22,053	283,643	315,180	377,223
US$ ('000)	315	4,046	4,508	5,396
Economic returns to water				
Rupees ('000)	16,748	215,707	240,046	277,773
US$ ('000)	239	3,083	3,431	3,971

Source: Primary survey data collected in KOISP July 1999.
[a]From table 5.
[b]Average irrigated paddy acreage as shown in table 1.
[c]In scenario 1, the irrigation intensity is 200% in the Old Area and 150% in the New Area. In the Old Area, all irrigable hectares (4,200) are under paddy cultivation in both seasons. In the New Area, following historical patterns, it is assumed that 20% of the irrigable area is under OFC cultivation. Of the remaining irrigable area of 4,320 hectares (4,320 = 5,400 irrigable ha – 1,080 ha of OFCs), 100% is under paddy cultivation in maha and 50% is in yala.
[d]Scenario 2 is exactly the same as scenario 1 except that 100% of non-OFCs acreage (4,320 ha) is under paddy cultivation in yala.
[e]Average of New Area Right and Left Banks.

economic gains could be achieved. Scenarios 1 and 2 project the potential gains that could be obtained (table 7). In both scenarios, irrigation intensity in the Old Area is 200 percent. In scenario 1, irrigation intensity in the New Area is 150 percent (100% in maha and 50% in yala). In scenario 2, irrigation intensity in the New Area is 200 percent. In both scenarios, it is assumed that 20 percent of irrigable hectares in the New Area are devoted to the production of OFCs.

Scenario 1, with an 11 percent (1,436 hectares) increase in irrigated paddy area, provides a financial gain of Rs 315 million (US$4.5 million) and an economic gain of Rs 240 million (US$3.4 million) per year. Scenario 2 increases irrigated paddy area by 32 percent from 1989–97 levels. These efficiency improvements would increase financial gains by an estimated Rs 93.6 million (US$1.3 million) per year and would provide for additional economic gains of Rs 62.1 million (US$887,800). These two examples illustrate that substantial gains from efficiency improvements could be obtained.

Achieving these economic gains will require significant changes in water allocation. The New Area will receive more water directly from Lunugamwehera. Reduction in the Old Area reservoir inflows from Lunugamwehera will be offset by higher return flows from the New Area, allowing for an increase in water recycling. However, as the percentage of drainage water inflows to the Old Area reservoirs increases, water quality could deteriorate. In addition to this, increased pressure on water resources in the Old Area to meet the 200 percent irrigation intensity target may result in a reduction of reservoir levels. Changes in the quality and quantity of water in the Old Area reservoirs may have important implications for the inland fisheries.

Economic Value of Inland Fisheries in the Kirindi Oya Basin

To better understand the current economic contribution of inland fisheries in the KOISP area and to identify the potential trade-offs incurred by changing water management practices, the financial and economic returns to fishery operations were estimated. Data collection efforts focused on three of the five reservoirs in the KOISP where commercial inland fisheries exist: Lunugamwehera, Wirawila, and Yoda Wewa. These three reservoirs account for about 81 percent (4,100 ha) of the total reservoir surface area in the project area.[17, 18] These reservoirs were selected for various reasons including relative importance of the commercial inland fisheries, variations in reservoir size, catchment characteristics, geographical dispersion, and expected differential impacts that would be caused by changes in water management practices. Lengthy surveys were conducted with 20 (12%) of the estimated 157 fisher boats operating in the three reservoirs.[19] Detailed information was collected on type of boat and nets in use, monthly catch data, amount of catch sold or consumed at home, prices received in wholesale and retail markets, and detailed cost information.

Inland fisheries are a relatively recent phenomenon in Sri Lanka. The fisheries are unique in that they are confined to artificial lakes and are essentially dependent on a single exotic species–the cichlid *Oreochromis mossambicus* or tilapia–introduced into Sri Lanka in the early 1950s. Tilapia constitutes up to 90 percent of all landings (figure 3). Inland fisheries have

[17]Commercial fishing occures at Tissa Wewa and at the Bandagiriya tank in the adjacent basin. Bandagiriya receives water from Lunugamwehera reservoir through the Right Bank tract. Commercial fishing does not occur at the remaining two small reservoirs in the basin, called Debera Wewa and Pannegamawa–with a combined surface area at full storage of about 185 hectares–due to heavy vegetative cover of the re servoir which prevents the use of gill nets. One area of future research could focus on the implications of vegetation removal from these reservoirs and the potential implications for fisheries and other uses of water.

[18]Estimates of surface area at full storage levels by reservoir varied slightly according to different sources. The estimated combined surface area for reservoirs in the basin ranges from 4,975 hectares to 5,094 hectares.

[19]Surveyed fisher boats by area are as follows: eight in Lunugamwehera with 87 boats (9%), six in Wirawila with 30 boats (20%), and six in Yoda Wewa with 40 boats (15%).

FIGURE 3.
Tilapai (Oreochromis mossambicus).

Source: Mary Renwick, IWMI, July 1999.

witnessed substantial growth since the 1950s, and accounted for approximately 20 percent of the total fish production in Sri Lanka by the late 1980s (De Silva 1988). The government played an important role in supporting the growth of inland fisheries. Throughout the 1970s and 1980s, the federal government provided subsidies for boat acquisitions by inland fisherman, for fish stocking programs, and for the development and enforcement of monitoring programs. The boat subsidy program provided 90 percent subsidies for fiberglass canoes with outriggers.

Over the 1990–94 period, the state discontinued patronage of the fisheries due to pressure from prominent Buddhist monks who argued that inland fisheries were incongruent with Buddhist teachings. Annual inland fish production declined markedly during this four-year period (Amarasinghe and De Silva 1999). In the absence of state monitoring programs, fishermen began using smaller mesh-size nets that resulted in overfishing. However, inland fisheries are now close to full recovery since the state renewed its support to these fisheries after the mid-1990s.

In Sri Lanka, technology in commercial inland fishing is limited. Reservoir fishermen almost exclusively use gill nets (De Silva 1988). Most fishermen use narrow fiberglass canoes with outriggers (figure 4). These crafts have replaced traditional indigenous boats, such as dugout canoes with outriggers and log rafts, owing to the 90 percent boat subsidy scheme initiated in 1981. Gillnetting usually occurs in the night. Fishermen set nets in the late afternoon and early evening hours, and return in the early morning to haul in the catch. However, some day-fishing does occur. Two men usually operate a single boat. Kirindi Oya inland fishermen operate an average of 318 days per year (26.5 days per month). Fishermen operating within the reservoirs are well seasoned, and have, on average, 19.8 years of experience of inland fishing. A relatively large number of the fishermen

FIGURE 4.
The inland fishing gear (notice bundles of nets).

interviewed owned their boats (70%). More than half the boat owners had secured their boats through government subsidy programs. Two-thirds of non-boat owners paid cash rents for their boats ranging from Rs 500 to Rs 700 per month (US$7.14 to US$10), the remaining third operated under share-of-the-catch arrangements, with payments ranging from 20–50 percent of the daily catch. The average size of the surveyed households was 5.1 members. Approximately half the households relied on fishing as the sole source of income. Agricultural production constituted the other most important income source for those households engaging in more than one income-generating activity.

Productivity of the Inland Fisheries

Catch per boat trip, known as the catch per unit effort (CPUE) provides a measure of the productivity of a given fishery. The average annual yield for each reservoir was estimated according to the CPUE for each surveyed boat, number of trips per month for each boat, and the estimated number of boats for each reservoir.

Table 8 shows the catch and yield data for the three inland fisheries Lunugamwehra, Wirwila, and Yoda Wewa. Survey data indicate an average CPUE of 35 kg with significant variability across reservoirs, ranging from approximately 21 kg per trip in Wirawila to 50 kg per trip in Lunugamwehera. The variations reflect, in part, differences such as size of reservoir, breeding and recruitment characteristics of the commercially important fish populations, habitat conditions such as nutrient availability, and the intensity of fishing activities in the reservoir.

Seasonal Changes in Productivity

Survey results indicate seasonal changes in total yield (figure 5). Yields exhibit a roughly bimodal annual pattern in each reservoir. The late summer and early autumn period, at the

TABLE 8.
Average catch per unit effort, fishing trips, number of boats, and total annual yield by reservoir, 1999.

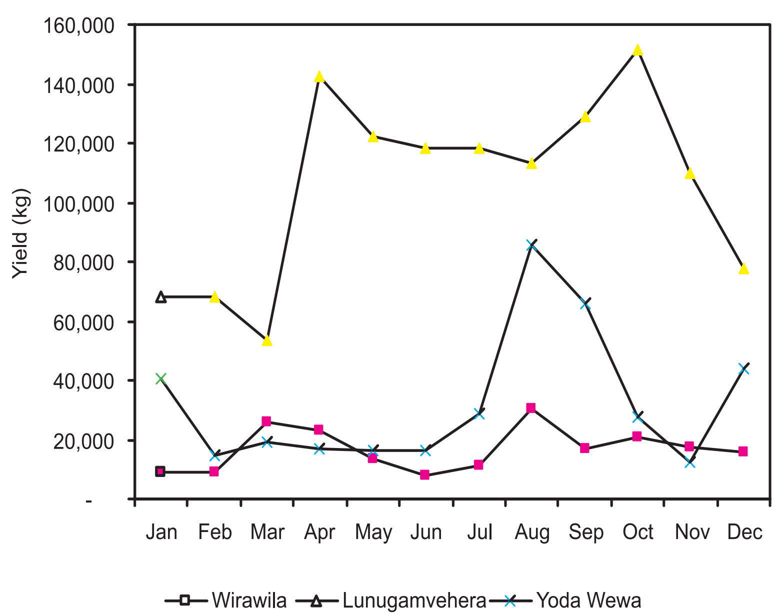
	Lunugamwehera	Wirawila	Yoda Wewa	Average
Catch *per trip* (kg)	50.0	20.6	33.8	34.8
Fishing trips *per month*	25.4	28.0	26.0	26.5
Number of boats[a]	87	30	40	157
Annual yield (mt)	1,354.5	225.3	421.8	2,001.6

Source: Primary survey data collected in KOISP July, 1999.

[a]See appendix D for background information on how the number of boats was estimated.

end of the dry season known as yala, corresponds to higher yields in all three reservoirs. However, the other peak yield period varies according to reservoir. Seasonal variability in yield and effort has been observed in a number of Sri Lanka's reservoirs (Amarasinghe and Pitcher 1986; De Silva and Fernando 1980 in De Silva 1988). Previous studies suggest that reservoir levels and water quality characteristics (such as alkalinity and electrical conductivity) may influence yields. However, the relationship between yields, levels, and water quality characteristics remains unclear. With regard to reservoir levels, study results remain contradictory. On the one hand, Amarasinghe (1999, 1987) found a correlation between decreasing reservoir levels and increasing yields. On the other hand, when De Silva (1988) compared mean monthly water levels and yield data for four reservoirs in southeastern Sri Lanka, he found no distinct trends in the yields. But, De Silva acknowledges that this may be due to data compilation over the years masking seasonal changes. De Silva

FIGURE 5.
Average total monthly yield by all fishermen by reservoir.



Source: Primary survey data collected in KOISP July, 1999 and M. Hemakumara (1999).

theorizes that fish become more vulnerable to gear as reservoir levels decline, resulting in higher yields.

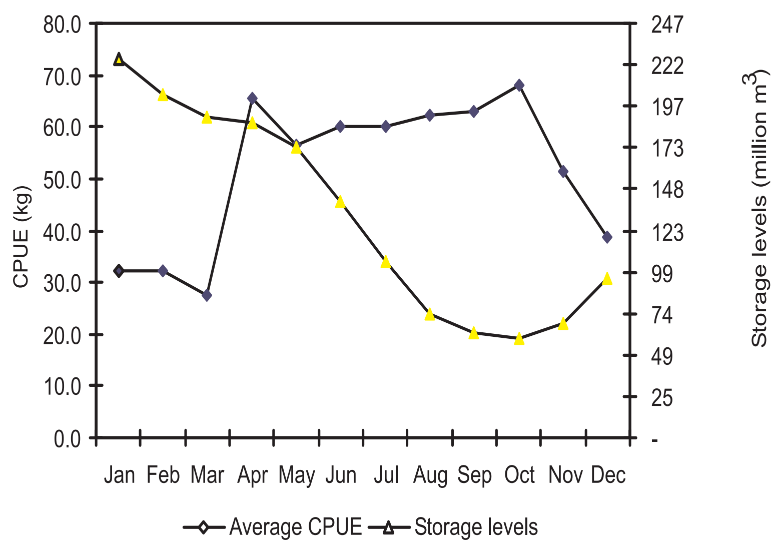
With regard to water quality, recent research by Nissanka et al. (1999) found a positive relationship between alkalinity and electrical conductivity of reservoir water and yield levels. Alkalinity and electrical conductivity correlated negatively with declining levels. This suggests that both reservoir levels and water quality may influence fisheries' productivity. More research is needed to improve the understanding of the relationship between water levels, water quality, biological productivity of fisheries, and yield.

Figure 6 shows average monthly CPUE and storage levels for Lunugamwehera. Although the data indicate a negative correlation between CPUE and storage levels, there is no obvious trend. To better understand the relationship between yield water levels, monthly fish yields were regressed on water storage levels and reservoir indicator variables.[20] The estimated coefficient on the storage level variable was negative and statistically significant (0.05 level) indicating a correlation between declining levels and increased CPUE.

Allocation of Catch between Market and Home Consumption

Table 9 shows the dispensation of average CPUE between home consumption and market sales. Each boat kept about 1.4 kg (4%) of the catch per trip, on average, for home consumption. This portion of the catch was generally divided between the fishermen operating the boat. With an average of 26.5 trips per month, it appears that fishermen and their families eat substantial amounts of tilapia.[21]

FIGURE 6.
CPUE and storage levels: Lunugamwehera.



Source: Primary survey data collected in KOISP July, 1999 and M. Hemakumara (1999).

[20]The average monthly CPUE was regressed on a constant, mean monthly storage levels (measured in MCM to avoid scale effects), and reservoir dummy variables for Lunugamwehera, Wirawila, and Yoda Wewa. The Yoda Wewa reservoir dummy variable was dropped in the estimation procedure to avoid the dummy variable trap. The model was estimated using ordinary least squares with robust standard errors to account for observed differences in CPUE variability among reservoirs.

[21]The nutritional importance of tilapia in the local diet, especially by fisherman and their families, with a particular concern for children and women of childbearing age, raises important questions as to health risks generated by water recycling, concentrations of agrichemicals in reservoirs, resulting in bioaccumulation of contaminants in fish.

TABLE 9.
Average catch per trip, home consumption and amount sold by reservoir, 1999.

	Lunugamwehera	Wirawila	Yoda Wewa	Average
Catch–CPUE (kg)	50.0	20.6	33.8	34.8
Home consumption (kg)	1.6	1.2	1.4	1.4
Market sales	48.4	19.4	32.4	33.4
Retail market				
Quantity sold (kg)	15.8	6.1	7.4	9.8
Price received (Rs/kg)	32.8	36.0	49.6	39.5
Wholesale market				
Quantity sold (kg)	32.6	13.3	25.1	23.7
Price received (Rs/kg)	20.5	28.7	26.1	25.1

Source: Primary survey data collected in KOISP, July 1999.

The remainder of the catch, 33.4 kg on average, was sold in wholesale and retail markets. Most of the marketed catch, approximately 67–77 percent, was sold to wholesalers at reservoir landings. The average price received in wholesale markets ranged from Rs 21 (US$0.3) per kilogram in Lunugamwehera, to Rs 29 (US$0.4) per kilogram in Wirawila with an overall average of Rs 25 (US$0.36) per kilogram. These differences reflect, in part, seasonal differences in the supply and demand for inland fish, quality differences in catch sold (cleaned or not cleaned) and marketing arrangements with wholesalers.

Retail sales, constituting a significantly smaller share of the total marketed catch, range from 23 percent in Yoda Wewa to 33 percent in Lunugamwehera. Retail marketing occurs in various ways, including direct sales to consumers at tank landings, door-to-door sales, sales in small retail fish markets and at roadside fish stands. The estimated average retail price received approximates Rs 40 (US$0.6) per kilogram. Although fish sales in retail markets fetch higher prices, retail marketing entails higher variable costs, primarily related to transportation and cooling costs.

Fishing-Related Costs

To examine the relative profitability of inland fisheries in the Kirindi Oya region, extensive data collection efforts focused on the costs associated with fishery operations. The gathering of detailed cost information is an important contribution to the literature on Sri Lankan inland fisheries, as there seem to be no other empirical cost studies. Table 10 shows the detailed average monthly costs, on a per-boat basis, for the three surveyed reservoirs. Incurred costs relate to boats, nets and other variable costs such as torches, baskets and boxes for hauling the catch and ice.[22] Both cash and noncash costs are included. Examples of noncash costs include depreciation of owned boats, household labor used for maintenance and repair of boats and nets, and returns to management. Returns to management capture the value of managerial know-how in commercial fishery operations.

[22]Costs related to reservoir operations and maintenance were not included because reservoirs are not currently managed for fishery purposes. Minimum reservoir levels must be maintained in each reservoir to ensure that water can be released through the gates that are located above the bottom of the reservoirs. During extremely dry years, the reservoirs have been allowed to dry completely, extinguishing local fish populations.

TABLE 10.

Average monthly costs per boat of inland fishery operations, by reservoir, 1999.[a]

Item	Type of cost[b]	Lunugamwehera	Wirawila	Yoda Wewa	Total
Boat					
Depreciation/rent/share[c]	C & N	2,676	77	961	1,238
Maintenance/repair					
Labor	N	171	108	177	152
Materials	C	317	208	46	190
Subtotal		3,164	393	1,184	1,580
Nets					
Replacement[d]					
New nets/materials	C	3,967	2,420	4,263	3,550
Labor for nets made	N	284	172	244	233
Maintenance/repair					
Labor	N	370	305	489	388
Materials	C	84	50	58	64
Subtotal		4,705	2,947	5,054	4,235
Other					
Batteries	C	541	433	498	490
Torch	C	57	70	76	68
Bulbs	C	28	29	37	31
IceC	186	362	35	194	
Baskets/styrofoam Boxes	C	101	72	164	112
Miscellaneous (transport costs, etc)	C	19	7	0	9
Returns of management[e]	N	1,542	866	1,222	1,210
Subtotal		2,474	1,839	2,032	2,114
Total cost[f]		10,343	5,179	8,270	7,929
Total cost/kg catch[g]		8.1	9.0	9.4	8.6

Source: Primary survey data collected in KOISP July, 1999.

[a]All costs are in rupees.

[b]C indicates cash cost and N indicates noncash cost. Cash costs include items such as boat rental, net replacement, boat and net repair materials and other variable costs of production. Noncash costs include boat depreciation and labor for boat and net maintenance and repair. Labor was valued at Rs 200 per day.

[c]These are weighted average costs that reflect differences in ownership. They include depreciation for boats and cash rents paid, or value of share-of-the-catch payments for non-boat owners. Estimates were weighted based on observed ownership characteristics and actual costs incurred.

[d]Net replacement costs include costs paid for new nets and materials and labor required to make nets. Costs were distributed by month depending on the reported expected life of each net.

[e]Estimated at 5% of total value of monthly production.

[f]Includes all cash and noncash costs.

[g]Equals total cost per boat divided by average monthly catch. Average monthly catch equals catch per trip multiplied by the average number of trips per month as shown in table 8.

For all three reservoirs, the average monthly cost per boat runs to about Rs 7,929 (US$113), with nets constituting the largest cost share (53%), followed by boats (20%). Variability in costs across reservoirs is due to differences in CPUE rather than any significant structural difference. Costs correlate positively with catch per unit effort. Average cost per kilogram of catch for each reservoir is as follows: Lunugamwehera (Rs 8.1/kg), Wirawila (Rs 9.0/kg), and Yoda Wewa (Rs 9.4/kg).

Value of Production, Costs, and Returns by Reservoir

Table 11 presents the average monthly value of production, associated costs of production, and returns. The value of production is estimated based on actual monthly CPUE data, number of trips per month, home consumption, amount sold by each fisherman to wholesale and retail markets, and actual prices received. Thus, the average monthly value of production represents

TABLE 11.
Average monthly value of production, costs and returns by reservoir, 1999.[a, b]

	Lunugamwehera	Wirawila	Yoda Wewa	Total
Value of production				
Marketed catch[c]	30,016	16,281	23,247	23,181
Home consumption[d]	831	1,044	1,188	1,021
Total value	30,847	17,325	24,435	24,202
Costs of production				
Cash costs[e]	5,488	3,652	5,293	4,811
Noncash costs[f]	4,855	1,527	2,977	3,118
Total costs	10,343	5,179	8,270	7,929
Returns				
Economic returns[g]	20,504	12,146	16,165	16,273
Per trip[h]	807	434	622	614
Financial returns[i]	19,673	11,102	14,977	15,252
Per trip[h]	775	397	576	576
Financial returns[j] excluding noncash costs	24,528	12,629	17,954	18,370
Per trip[h]	966	451	691	693

Source: Primary survey data collected in KOISP July 1999.

[a]Based on actual average monthly catch per trip, average trips per month, and wholesale and retail prices for marketed catch.

[b]All costs are in rupees.

[c]Average value of monthly catch sold in wholesale and retail markets.

[d]Estimated average value of home consumption based on the weighted average of retail and wholesale prices observed for marketed fish.

[e]Includes boat rental (for renters), boat and net maintenance and repair, and other variable cash costs such as torches, batteries, baskets, boxes, ice, and transportation.

[f]Noncash costs include family labor costs for boat and net maintenance and repair, and boat depreciation. Labor costs are estimated at the rate of Rs 200 per day. Boat depreciation constitutes a relatively small share of total noncash costs: Lunugamwehera Rs 116 (4%), Wirawila Rs 77 (15%), Yoda Wewa Rs 3 (<1%), and Total Rs 65 (4%).

[g]Equal the total value of production less total costs of production.

[h]Based on monthly mean number of trips as follows: Lunugamwehera (25.4), Wirawila (28.0), Yoda Wewa (26.0) and total average (26.5).

[i]Equal value of marketed catch less total costs of production.

[j]Equal value of marketed catch less total cash costs of production.

a weighted average of wholesale and retail marketing activities and concomitant prices. The estimated average monthly total value of the catch per boat is Rs 24,202 (US$346). This includes the value of fish consumed at home, estimated at Rs 1,021 (US$14.6) per boat per month. The value of the catch varies from one reservoir to another, reflecting their differences in CPUE and the average number of trips per month. For all three reservoirs, the average monthly total cost per boat for fishery related operations is Rs 7,929 (US$113), which includes both cash and noncash costs. Although costs vary by reservoir, reflecting differences in the catch, they approximate 32 percent of the total value of production in each reservoir.

Estimated average returns per boat were measured in the following three ways: economic returns, financial returns, and financial returns excluding noncash costs. Economic returns provide a measure of the total value and costs associated with fishery operations. The total value of production accounts for the value of both marketed fish and fish consumed at home. The total costs include noncash inputs such as labor and depreciation of fixed assets, as well as all cash costs. For all three reservoirs, the average monthly economic return per boat equals Rs 16,273 (US$232). On a per-trip basis, the economic returns per boat equal Rs 614 (US$8.7) or Rs 307 (US$4.4) per fisherman. On an annual basis, economic returns to the average fisherman average Rs 97,626 (US$1,395).

Estimates of financial returns include only the value of marketed fish. However, they do include all cash and noncash costs. Financial returns provide a measure of the longer-term viability of an enterprise on a purely commercial basis. They are considered a longer-term measure because the fixed costs of assets, as well as the opportunity costs of family labor and management are included. Average monthly financial returns are slightly lower than economic returns because they exclude the value of home consumption. The average monthly financial returns per boat equal Rs 15,252 (US$218). Thus, the average fisherman earns approximately US$1,308 per annum.[23] Financial returns that exclude noncash costs provide a shorter-run measure of financial performance because they include only short-run day-to-day cash operating expenses. The average monthly financial returns, excluding noncash costs equal Rs 18,370 (US$262) or Rs 693 (US$10) per trip and provide an additional measure of the relatively sound performance of inland fisheries.

Annual returns to all of the five commercially important fisheries in the KOISP were estimated based on actual monthly returns to fisherman, by reservoir, for the three surveyed reservoirs (table 12). Total annual economic returns to the five reservoirs from inland fishing are Rs 38.1–39.6 million (or US$544,000–566,000) per year. Thus, the value of fisheries is about 18 percent of the total economic returns to water in irrigated paddy production.[24] These results demonstrate the economic importance of the inland fisheries. They also raise a number of important questions:

- How will changes in water management strategies, implemented to achieve a 200 percent level of irrigation intensity affect this important industry?

- Could the productivity of existing inland fisheries be improved and by how much?

---

[23]Based on US$218 per boat per month times 12 months divided by two fishermen or US$1,308 = [(US$218 returns/boat/month)*(12 months)]/(2 fishermen).

[24]Based on 1989 average annual economic returns of approximately Rs 3.1 million, as shown in table 7.

TABLE 12.
Estimated total annual returns to all KOISP inland fisheries.

	Lunugamwehera Wirawila and Yoda Wewa[a]	Tissa Wewa and Bandagirya[b]	Total[c]
Returns			
Economic returns[c]			
Rupees ('000)	33,538	4,549–6,066	38,087–39,604
US$ ('000)	479	65–87	544–566
Financial returns[d]			
Rupees ('000)	31,724	4,195–5,593	35,919–37,317
US$ ('000)	453	60–80	513–533
Financial returns[e] excluding noncash costs			
Rupees ('000)	38,772	4,937–6,582	43,708–45,354
US$ ('000)	554	71–94	624–648

Source: Primary survey data collected in KOISP July 1999.

[a]Based on the following estimated number of boats for each reservoir: Lunugamwehera (87 boats), Wirawila (30 boats), and Yoda Wewa (40 boats).

[b]Returns from Tissa Wewa and Bandagirya estimated based on average returns from Wirawila and Yoda Wewa. The lower estimate equals 75% of average returns from Wirawila and Yoda Wewa and the upper bound estimate equals 100% of the average.

[c]Equal the total value of production less total costs of production.

[d]Equal value of marketed catch less total costs of production.

[e]Equal value of marketed catch less total cash costs of production.

- What are the possibilities for expanding fishery operations in the KOISP?

Available research by fisheries' biologists is inconclusive with regard to the potential biological consequences of fluctuations in water quality and levels. More research is needed to understand how these factors may influence the biological productivity of fisheries.

Conclusions, Policy Implications, and Future Research

An improved understanding of the relative economic contributions of the mutliple uses of irrigation system water is crucial to the design and implementation of effective water management strategies. Identifying and assessing potential impacts among different user groups in a multiple-use irrigation system is a complex task. This research takes a first step in this direction by examining the value of water in irrigated paddy and fisheries KOISP and the potential implications of changes in water management on these water uses.

Agriculture

The financial returns to paddy production are about US$315 per hectare each season, demonstrating the dire need to improve water management so that sufficient water supplies exist to enable farmers in both the Old and New Areas to grow two crops per year (200% irrigation intensity). Farmers with adequate water supply availability who can produce two crops per year will earn an annual cash income of approximately US$630 per hectare.

The average economic returns to water in irrigated paddy production were US$239 per hectare and ranged from US$197 in the New Area Left Bank to US$267 in the Old Area. Economic returns to water can be interpreted as the incremental contribution of water to the value of total output. Under this interpretation, 26 percent of the total value of output per hectare, on average, can be attributed to water.

The annual financial returns to paddy production are about US$4 million. The estimated total annual value of water in irrigated paddy production is US$3.1 million per year for the KOISP. This represents the economic contribution of water in paddy production to the local economy. To estimate the total economic contribution of water to the local economy would require estimates of the value of water in all its other uses. Economic gains associated with improvements in water management to achieve higher levels of cropping intensity were also estimated. If an irrigation intensity of 200 percent could be achieved with the same water resources, economic returns to water would increase to approximately US$4 million, representing an annual economic gain of about US$888,000 to the local economy. The increase in agricultural productivity and concomitant economic gains associated with higher irrigation intensities will work towards alleviating poverty among the poorest households in the Kirindi Oya area. Realizing these economic gains will require significant changes in water management. These changes may influence the quantity and quality of water in the reservoirs where the fisheries are located.

Fisheries

The combined total annual yield from the three reservoirs studied was approximately 2,000 metric tons. Economic returns were estimated to measure the net contribution of fisheries to the local economy. Economic returns equal the value of the total catch less all cash and non-cash costs associated with fishery operations. The total annual net economic contribution of all five commercially important fisheries in KOISP is estimated to be about US$544,000–US$566,000 per year. Fisheries represent an important economic contribution of the KOISP, adding approximately 18 percent of the value of the KOISP annual paddy production over the 1989–97 baseline period. At present, fisheries are not recognized in water management and allocation decisions. These result demonstrate the importance of recognizing and assessesing the value of water in nonirrigation uses.

The estimated financial returns to KOISP fishery operations were estimated to be approximately US$513,000–US$533,000 per year. Financial returns measure the value of only marketed catch less all cash and noncash costs and provide an estimate of the relative financial profitability of fisheries. Average financial returns per fisherman were estimated at US$1,308 per year, exceeding those of irrigated agriculture. These results highlight the potential of fisheries as a potential poverty alleviation tool.

The implications of potential change in reservoir water quality and levels on biological productivity of the fisheries are unclear. Although inland fisheries' biologists in Sri Lanka have observed a correlation between declining levels and increased yields, the underlying relationship is not well understood. Equally perplexing is the relationship between increasing alkalinity and electrical conductivity levels and higher yields. Further research is needed to better understand the relationship between reservoir levels and biological productivity of the fisheries. Water recycling may increase concentrations of toxic agrochemicals in the reservoirs. Further research is needed to better understand the relationship between water_recycling, concentration of potentially toxic chemicals, bioaccumulation of these chemicals in fish and the potential health implications associated with local consumption patterns of fish, especially by children and women of child-bearing age. Further hydrological research is needed to identify the alternative water management strategies required to meet the 200 percent irrigation intensity target.

Appendix A

A model for estimating the value of water in irrigated crop production

In the generalized theoretical model, each agricultural producer (i) maximizes profits, π_i, by choosing the volume of irrigation water, w_{ij}, capital, k_{ij}, labor, l_{ij}, and other non-water inputs, z_{ij}, for each crop (j). Producers face a water allocation constraint, A_i, reflecting their water-use right or entitlement. Producers are assumed to pay a per-unit price for allocated water. This price may reflect subsidies or the indirect costs associated with securing irrigation water. The producer-level decision problem takes the following form:

$$\text{Max } \pi_i = \sum_j P_j f_{ij}(w_{ij}, k_{ij}, l_{ij}, z_{ij}) - (P^w w_{ij} + P^k k_{ij} + P^l l_{ij} + P^z z_{ij}) \quad (1)$$

$$\text{Subject to: } \sum_j w_{ij} \le A_i$$

$$w_{ij} > 0, k_{ij} > 0, l_{ij} > 0, z_{ij} > 0$$

where, P_j is the output price received from the j^{th} crop; $f(.)$ is a well-behaved production function and satisfies all regularity conditions; and P^w, P^k, and P^l are the input prices for water, capital, and labor. For simplicity, P^z represents a composite array of prices for other non-water inputs such as land, pesticides and fertilizers. The first order conditions for an interior solution to (1) are:

$$P_j f_{ij}^w - P^w - \lambda_i = 0 \quad \forall i, j \quad \text{(2a)}$$

$$P_j f_{ij}^k - P = 0 \quad \forall i, j \quad \text{(2b)}$$

$$P_j f_{ij}^l - P^l = 0 \quad \forall i, j \quad \text{(2c)}$$

$$P_j f_{ij}^z - P^z = 0 \quad \forall i, j \quad \text{(2d)}$$

$$A_i - \sum_j w_{ij} = 0 \quad \forall i \quad \text{(2e)}$$

where,

$P_j f_{ij}^x \equiv VMP_x$ value of marginal product identity x = w,k,l,z (2f)

f_{ij}^x = partial derivative of $f_{ij}(.)$ with respect to variable x or $\frac{\partial f_{ij}(.)}{\partial x}$

λ_i = is the Legrange multiplier on water allocation constraint

The Legrange multiplier, λ_i, reflects both the allocation constraint and the concomitant supply that producers' profits are maximized when the volume of irrigation water (w_{ij}) applied to each crop (j) is chosen so that the marginal value product (VMP) for water for each crop equals the price of water plus the opportunity cost of the allocation constraint ($P_j f_{ij}^x = P_w + \lambda_i$). The first order conditions also imply that quantities of all other inputs are selected so that the VMP of each input equals its price.

According to Euler's theorem, the total value product (TVP) of the output will be exactly exhausted if each input is paid according to its marginal productivity (or VMP), under the assumption of CRS.[25] Using Euler's theorem, the total value of output at the optimum *(TVP*)* is divided into shares based on the contribution of each input as follows:

$$TVP_{ij} = (VMP_w w_{ij} + VMP_k k_{ij} + VMP_l l_{ij} + VMP_z z_{ij}) \quad (3)$$

where,

$TVP_{ij}^* = P_j Q_{ij}^*$ and Q_{ij}^* is the optimal quantity of final output produced.

Rearranging (3) and using the VMP identity (2f) and the first order conditions (2a – 2e):

$$(P^w + \lambda_i) w_{ij} = P_j Q_{ij}^* - (P^k k_{ij} + P^l l_{ij} + P z_{ij}) \quad (4)$$

Solving (4) for the value of water in its current use we get:

$$P^w + \lambda_i = (P_j Q_{ij}^* - (P^k k_{ij} + P^l l_{ij} + P z_{ij}))/w_{ij} \quad (5)$$

The value of water in its current use, $P^w + \lambda_i$, reflects both the implicit or explicit cost of securing water and the scarcity value of the resource, based on its attributes. If appropriate prices can be assigned to output and all inputs in (5) except water, the remaining portion of the total value of the product is imputed to the residual input– water.

[25]Euler's theorem can also be generalized to hold for nonhomogeneous technology structures (Chiang 1984). This requires zero long-run profits or zero industry profits even if individual producers are realizing nonzero profits in the short run. The latter can be established under free exit and entry into the industry.

Appendix B

Background calculations on per-hectare water deliveries, consumption use, drainage, and depletion

Total	Old Area	New Area	Total
Irrigated area[a]			
KOISP			
Paddy	7,504	5,397	12,901
OFCs[b]		2,121	2,121
Total	7,504	7,518	15,022
Water deliveries[c]			
(MCM)	99	169.999	269.298
(m^3/ha)	13,233	22,612	17,923
Consumptive use[d]			
(MCM)	6.236	6.247	12.483
(m^3/ha)	831	831	831
Drainage [e]			
(MCM)	68.116	28.180	96.296
(m^3/ha)	9,077	5,221	6,409
Depletion[f]			
(MCM)	74.350	45.499	108.759
(m^3/ha)	9,908	6,052	7,240

Source: M. Hemakumara. 1999.

[a]1989–97 irrigated area as shown in table 1.

[b]For water accounting purposes, it is assumed that all irrigated OFCs are cultivated in the New Area.

[c]Water deliveries for the New Area for 1990–98 are average deliveries from Lunugamwehera. They include deliveries to the Right and Left Bank main canals less the Ellegala diversion. The maha season is assumed to run from October to March and the yala season from April to September. Water deliveries for the Old Area include 1998 issuances from Wirawila, Debera Wewa, Tissa Wewa, and Yoda Wewa. Since there was only one calendar year of deliveries (crossing maha season), seasonal averages could not be estimated. Per-hectare deliveries equal total deliveries (per area and season) divided by irrigated hectares.

[d]Per-hectare consumptive use equals evapotranspiration averaged over the yala and maha seasons. For yala, consumptive use equals actual pan evaporation of 1,128 mm times .85 pan coefficient = 959 mm times one hectare (1,000 m^2). For maha, consumptive use equals actual pan evaporation of 827 mm times .85 pan coefficient = 703 mm times one hectare (1,000 m^2) (Renault 1999).

[e]Drainage for the New and Old Areas equals 1998 outflows from Weligatta and the Kirindi Oya River, respectively. Per-hectare drainage equals total deliveries (per area and season) divided by irrigated hectares.

[f]Depletion equals drainage plus consumptive use, as measured by evapotranspiration. Per-hectare depletion equals total depletion divided by irrigated hectares.

Appendix C

Assumptions used to estimate the value of water in paddy production

Yields

Reported yields were adjusted downwards by 25 percent because of a suspected upward bias in reported yields across survey respondents. The average unadjusted yield was approximately 6,500 kilograms of paddy per hectare. It is unclear whether yields were biased upward due to overestimation on the part of interviewed producers or bias on the part of the interviewer. However, overreporting of actual yields in Sri Lanka is well documented in the literature (Harris 1977; Dias 1977). After numerous consultations with individuals cognizant of agricultural practices in the Kirindi Oya area it was deemed prudent to adjusted yields downward by 25 percent. All other reported quantities of inputs and costs appeared reasonable for the area.

Value of Output

Consumed paddy was valued at the reported farm gate price of paddy received. The value of production equals the value of marketed plus home-consumed paddy.

Family Labor

Family labor was valued using mode wage rate for the respective activity, as indicated below, except for irrigation. Labor for irrigation was valued at Rs 50 per day assuming irrigation operations take
2 working hours. The wage rate was Rs 200 for an 8-hour workday. Imputed daily wage rates (in Rs) by activity were as follows:

Plowing = 200.
Leveling = 200.
Bund construction = 200.
Broadcasting = 200.
Hauling = 200.
Threshing = 350.
Winnowing = 350.
Packing = 200.
Transportation = 200.
Fertilizer application = 200.
Pesticide application = 200.

Chemical and Fertilizer Costs

Chemical costs equal the sum of material costs for herbicides, insecticides and fungicides used in plant protection operations. Fertilizer cost is the sum of material cost for fertilizer used.

Seed

Reported costs for purchased seed. No respondent reported using own seed.

Machinery Related Costs (for owners)

Machinery cost for owners was valued by accounting for depreciation per season, assuming two seasons per year. For depreciation purposes, the economic life of tractors and hand sprayers was assumed to be 10 years and for power threshers it was assumed to be 5 years. When machinery was used for longer than the assumed economic life, the actual life of the machine was used as the economic life for depreciation purposes.

Labor for operation and maintenance of machinery and equipment labor was valued at Rs 200 per day. Material costs for operation and maintenance were taken as reported.

Land Cost

The majority of the agricultural land in the KOISP is either government allotted or privately owned. For surveys with unreported (missing) land and rental values, seasonal land costs were imputed. The imputed seasonal land cost for owned land in the Old Area was set equal to the mode lease rate of Rs 12,500.00 (US$179) per hectare. The imputed seasonal land cost for land allotments in the New Area was set equal to Rs 10,000.00 (US$143) per hectare.

Returns to Management

Returns to management capture the value or cost of managerial know-how and were estimated at 5 percent of the total value of production. Five percent is a relatively standard rate for field crops (Young 1996).

Operating Interest

Operating interest is 4 percent of all cash costs related to crop establishment and crop care, and is 0.06 percent of all cash costs in harvesting. Annual market lending rate is assumed to be 15 percent. Operating interest is considered as a cash cost.

Returns

Financial returns equal the value of marketed output less cash costs. Economic returns equal the total value of output (marketed and home consumed) less all cash and noncash costs.

Appendix D

Estimates of the number of commercial fishing crafts used for the study

Reservoir	CEA Report (1994)	Ministry of Fisheries and Aquatic Resources (1997)	Fishermen association interviews (1997)	Interview with fishermen association leaders (1999)	Number of boats estimated for this study (and rationale)
Lunugamwehera	-	87	120	-	87[d]
Wirawila	30	27	16	30[b]	30[e]
Tissa Wewa	20	8	14[a]	-	14[f]
Yoda Wewa	31	51	40–50	35–80[c]	40[g]
Bandagiriya	-	9	25	-	17[f]

[a]Includes 11 "tourist" boats. It is unclear from IWMI field staff interview notes whether these are used for commercial fishing or not. It seems reasonable to assume that at least a portion of them is used for fishing.
[b]Thirty boats used "day and night" according to field interviews with fisherman association leaders conducted during July 1999.
[c]The "official" number of boats is 35 but the estimate of the head of the fisherman's cooperative is 80.
[d]Personal communications with fisheries' biologists and others working in the Kirindi Oya area believe the estimate of 120 boat to be high. Therefore, the more conservative estimate of 87 boats is selected.
[e]Three of the four sources agree on the estimate of approximately 30 boats and thus, this number is selected.
[f]Without further information, the mean number from all reported studies is selected.
[g]The official limit on the number of boats in Yoda Wewa is approximately 30–35. However, unofficial boats are also used for fishing activities. Thus, a moderately conservative estimate of 40 boats is used for the analysis.

Literature Cited

Amarasinghe, U. *Fishery of a tropical reservoir: The effect of fluctuations in the water level on the fishery of a shallow, irrigation reservoir.* Kelaniya, Sri Lanka: Department of Zoology, University of Kelaniya. Unpublished.

Amarasinghe, U. 1987. Status of the fishery of Pimburettewa: A man-made lake in Sri Lanka. *Aquatic Fisheries Management* 18: 375-83.

Amarasinghe, U.; and T. J. Pitcher. 1986. Assessment of fishing effort in Parakrama Samudra: An ancient man-made lake in Sri Lanka. *Fisheries Resources* 4: 271-81.

Amarasinghe, U.; and S. De Silva. 1999. Sri Lankan reservoir fishery: A case for introduction of a co-management strategy. *Fisheries Management and Ecology* 6: 1-13.

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

Brewer, J. D. Negotiating water allocation rules in a government managed irrigation system: Conflicts in Kirindi Oya. In *Negotiating water rights*, ed. B. Bruns and R. Meinzen-Dick. New Delhi, India: Sage Press. Unpublished.

Chiang, A. C. 1984. *Fundamental methods of mathematical economics,* Third edition. New York: McGraw-Hill.

De Silva, S. 1985. Observations on the abundance of the exotic Cichlid Sarotherodon mossambicus in relation to fluctuations in a man-made lake in Sri Lanka. *Aquatic Fisheries Management* 16: 91-102.

De Silva, S. 1988. *Reservoirs of Sri Lanka and their fisheries*. FAO Fisheries Technical Paper 298. Rome, Italy: Food and Agriculture Organization.

De Silva, S.; and C. H. Fernando. 1980. Recent trends in the fishery of Parakrama Samudra: An ancient man-made lake in Sri Lanka. In *Ecology and Development*, ed. J. I. Furtado. Kuala Lumpur: University of Malaya Press.

Dias, H. D. 1977. Selective adoption as a strategy for agricultural development: Lessons from southeast Sri Lanka. In *Green revolution? Technology and change in rice growing Areas of Tamilnadu and Sri Lanka*, ed. B. H. Farmer, 54-84. London: Macmillan.

Dixon, John. 1991. Economic valuation of environmental resources. In *Development research: The environment challenge*, ed. J. Winnpenny. London: Overseas Development Institute.

Dixon, John; L. F. Scura; R. A. Carpenter; and P. B. Sherman. 1994. *Economic analysis of environmental impacts* Second edition. London: Earthscan Publications Ltd.

Dharmasena, G. T. 1988. Review of water resources of Kirindi Oya basin at Lunugamwehera. *Hydrological Annual 1987/88*. Colombo, Sri Lanka: Hydrology Division of the Irrigation Department.

Freeman, A. Myrick III. 1993. *The measurement of environmental and resource values: Theory and methods.* Washington, D.C.: Resources for the Future.

Harris, B. 1977. Paddy and rice statistics in Sri Lanka. In *Green revolution? Technology and change in rice growing areas of Tamilnadu and Sri Lanka*, ed. B. H. Farmer, 7-19 London: Macmillan.

IWMI (International Water Management Institute). 1995. *Kirindi Oya project impact evaluation study.* Colombo, Sri Lanka.

IWMI. 1998. *Multiple uses and water quality*. Report submitted to the Council of Agriculture and the Agricultural Engineering Research Centre of the Republic of China. Colombo, Sri Lanka.

Marikar, F. 1999. Description of the study area. In *Multiple uses of water in irrigated areas: A case study from Sri Lanka*, ed. M. Bakker, R. Barker, R. Meinzen-Dick, and F. Konradson. System-Wide Initiative on Integrated Management (SWIM) Colombo, Sri Lanka: International Water Management Institute.

Meinzen-Dick, Ruth; and Margaretha Bakker. 1999. Irrigation systems as multiple-use commons: Water use in Kirindi Oya, Sri Lanka. *Agriculture and Human Values* 6(3).

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

Munasinghe, Mohan. 1992. *Water supply and environmental management: Developing world applications.* Boulder and Oxford: Westview Press.

NRC (National Research Council). 1996. *Economic valuation of groundwater.* Washington, D.C.: National Academy of Science. Unpublished.

Nijman, C. 1992. *Irrigation decision-making processes and conditions.* International Irrigation Management Institute Country Paper – Sri Lanka Number 9. Colombo, Sri Lanka: International Irrigation Management Institute.

Nissanka, C.; U. Amarasinghe; and S. De Silva. Forthcoming. *Yield prediction in reservoir fisheries.* Kelaniya, Sri Lanka: Department of Zoology, University of Kelaniya.

Pearce, David W. 1993. *Economic values and the natural world.* Cambridge: MIT Press.

Randall, Alan. 1991. Total and nonuse values. In *Measuring the demand for environmental quality. Contributions to economic analysis*, ed. John Braden and Charles Kolstad, 198. Amsterdam, Oxford and Tokyo: North-Holland.

Renault, D. 1997. *Proposal and technical background for KOISP 200 for 2000*. Colombo, Sri Lanka: International Water Management Institute.

Renault, D. 1999. IWMI internal memorandum, June 1999. Colombo, Sri Lanka: International Water Management Institute.

Sri Lanka Department of Natural Planning. 1992. *River basin study.* Colombo, Sri Lanka: Sri Lanka Department of Natural Planning.

van Eijk, A.; D. Molden; and R. Sakthivadivel. 1999. Water uses in the Kirindi Oya sub-basin. In *Multiple uses of water in irrigated areas: A case study from Sri Lanka* (SWIM Paper 8), ed. M. Bakker, R. Barker, R. Meinzen-Dick and K. Flemming. Colombo, Sri Lanka: International Water Management Institute.

Winkler, H. 1983. The ecology of cormorants (genus Phalacrocorax). In *Limnology of Parakrama Samudra, Sri Lanka*, ed. F. Schiemer. The Hague: Junk Publishers.

Winpenny, J. T. 1991. *Values for the environment: A guide to economic appraisal*. London: Overseas Development Institute.

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

Research Reports

38. *An Assessment of the Small-Scale Irrigation Management Turnover Program in Indonesia.* Douglas L. Vermillion, Madar Samad, Suprodjo Pusposutardjo, Sigit S. Arif, and Saiful Rochdyanto, 2000.

39. *Water Scarcity and the Role of Storage in Development.* Andrew Keller, R. Sakthivadivel, and David Seckler, 2000.

40. *Using Datasets from the Internet for Hydrological Modeling: An Example from the Küçük Menderes Basin, Turkey.* Martin Lacroix, Geoff Kite, and Peter Droogers, 2000.

41. *Urban-Wastewater Reuse for Crop Production in the Water-Short Guanajuato River Basin, Mexico.* Christopher A. Scott, J. Antonio Zarazúa, and Gilbert Levine, 2000.

42. *Comparison of Actual Evapotranspiration from Satellites, Hydrological Models and Field Data.* Geoff Kite and Peter Droogers, 2000.

43. *Integrated Basin Modeling.* Geoff Kite and Peter Droogers, 2000.

44. *Productivity and Performance of Irrigated Wheat Farms across Canal Commands in the Lower Indus Basin.* Intizar Hussain, Fuard Marikar, and Waqar Jehangir, 2000.

45. *Pedaling out of Poverty: Social Impact of a Manual Irrigation Technology in South Asia.* Tushaar Shah, M. Alam, M. Dinesh Kumar, R. K. Nagar, and Mahendra Singh. 2000.

46. *Using Remote Sensing Techniques to Evaluate Lining Efficacy of Watercourses.* R. Sakthivadivel, Upali A. Amarasinghe, and S. Thiruvengadachari. 2000.

47. *Alternate Wet Dry Irrigation in Rice Cultivation: Saving Water and Controlling Malaria and Japanese Encephalitis?* Wim van der Hoek, R. Sakthivadivel, Melanie Renshaw, John B. Silver, Martin H. Birley, and Flemming Konradsen. 2000.

48. *Predicting Water Availability in Irrigation Tank Cascade Systems: The CASCADE Water Balance Model.* C. J. Jayatilaka, R. Sakthivadivel, Y. Shinogi, I. W. Makin, and P. Witharana. 2000.

49. *Basin-Level Use and Productivity of Water: Examples from South Asia.* David Molden, R. Sakthivadivel, and Zaigham Habib. 2000.

50. *Modeling Scenarios for Water Allocation in the Gediz Basin, Turkey.* Geoff Kite, Peter Droogers, Hammond Murray-Rust, and Koos de Voogt. 2001.

51. *Valuing Water in Irrigated Agriculture and Reservoir Fisheries: A Multiple Use Irrigation System in Sri Lanka.* Mary E. Renwick. 2001.

Postal Address:
P O Box 2075
Colombo
Sri Lanka

Location:
127, Sunil Mawatha
Pelawatte
Battaramulla
Sri Lanka

Tel:
+94-1-867404

Fax:
+94-1-866854

E-mail:
iwmi@cgiar.org

Website:
http://www.iwmi.org

INTERNATIONAL WATER MANAGEMENT INSTITUTE

FUTURE HARVEST
IWMI is a Future Harvest Center supported by the CGIAR

ISSN 1026-0862
ISBN 92-9090-439-9