Multiple Uses and Water Quality

Report Submitted to the
Council of Agriculture and the Agricultural
Engineering Research Center
of the
Republic of China

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Since 1997, the Council of Agriculture (COA) and the Agricultural Engineering Research Center (AERC) of the Republic of China (ROC) have supported research on the water quality component of the ongoing research project in the System Wide Initiative of Water Management program carried out by the International Irrigation Management Institute. This report is a summary of the activities during the period 1997 to the first quarter of 1998. It is noted that any information on the project besides that described in this report is available upon request. The report mainly gives a review of available documents, descriptions of the study areas and methodologies used. Studies are ongoing and results will be provided in subsequent progress reports.

International Irrigation Management Institute (IIMI), 1998. Multiple Uses and Water Quality: Report Submitted to the Council of Agriculture and the Agricultural Engineering Research Center of the Republic of China. Colombo, Sri Lanka: IIMI.

Cover photograph: Courtesy Studio Times, Sri Lanka.

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Background

In 1997, the CGIAR started a System-Wide Initiative on Water Management (SWIM). One of the SWIM studies coordinated by the International Irrigation Management Institute (IIMI) was on "Multiple Uses of Water in Irrigated Area." The goal of that study is to ensure that irrigation and water resources policies take into account all uses and users of water, so that water will be used in an efficient, equitable and sustainable manner to reduce poverty and improve well-being.

The objectives of the multiple uses study are to

- define, describe and value the multiple uses of irrigation water.
- assess the impact of multiple uses of irrigation water on health and the environment.
- identify the interactions and conflicts among sectors and users for irrigation water.
- assess the productivity and equity impacts of water withdrawals on users and sectors taking into account all uses and users.

Further, there is a need for a better understanding of how people use water and of the environmental implications of agriculture on human and animal health, and on aquatic life. It is assumed that availability and quality of water influences the use pattern and choice of sources of a rural society. Therefore, the objectives of the water quality component of the study include:

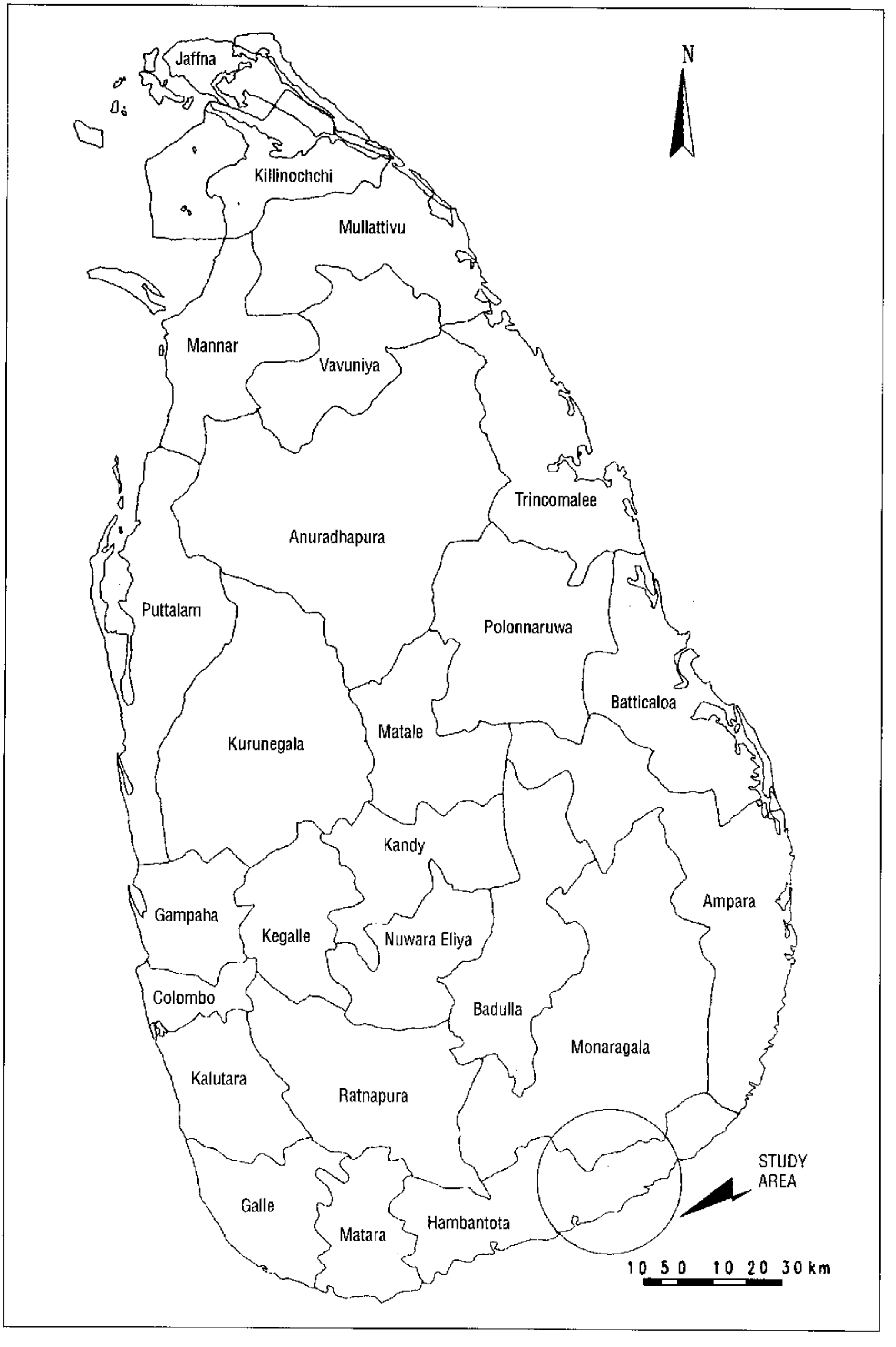
- identifying the household choices of water sources for domestic use and the factors influencing their choice
- assessing the potential environmental and health risk to those benefiting from the water from each source, with special emphasis on irrigation water

The Kirindi Oya Irrigation System located in the southern part of Sri Lanka and the irrigated area around the Hakra 6/R distributary in the southern Punjab of Pakistan were selected as case study sites. The preliminary phase of the study identified the sources, uses, users of water, reasons for water use by source, and problems associated with water access by different groups within selected areas of each irrigation system. Additional work during this phase has characterized and described the survey sites. This included the production, ecological, hydrological systems, and the social and institutional arrangements that guide rights and access for different water uses.

METHODS AND ACTIVITIES

The majority of the information in the first phase of the study was obtained from interviews with policy makers and implementers within relevant institutions, analysis of secondary sources such as maps, legal statutes and manuals of operation, and direct observation used to identify strategies and constraints in accommodating multiple water uses. Focus group discussions with user groups were also made and household questionnaires were used to obtain initial quantification of the variables of interest. In Pakistan, secondary sources were used to obtain an epidemiological profile which included an assessment of the incidence of watery diarrhea, dysentry, eye infections and skin infections. In Sri Lanka, water samples were taken and analyzed to measure the quality levels of the water sources of importance for the study area.

Figure 1. Map of Sri Lanka showing the study area



Case Study in Sri Lanka: Multiple Uses of Water in the Kirindi Oya Irrigation System

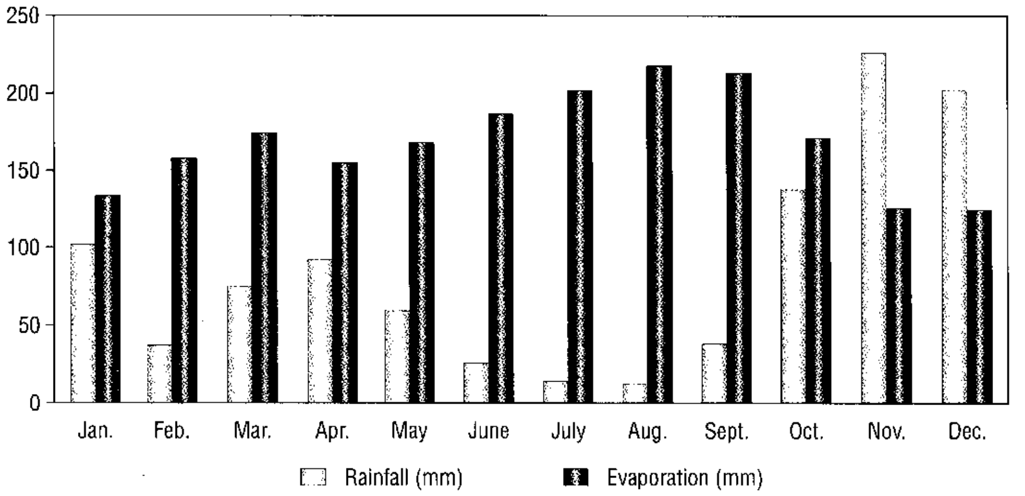
(Report compiled by Y. Matsuno, IIMI HQ, Sri Lanka)

SITE DESCRIPTION

Physical description

The study site, Kirindi Oya Irrigation System is located in the south eastern dry zone of Sri Lanka [Figure 1]. It falls within the agro-ecological region of the Dry Zone Low Country (DL_5) which represents a semi-arid tropical environment. The 100-year mean annual rainfall of the project area is 970 mm and of this amount 67% occurs in the maha (wet) season from October to February and 29% in the yala (dry) season from March to August. Temperature is nearly constant and remains within 26^0 to 28^0 C. The 20-year mean annual evaporation of class A open pan is 2000 mm and evaporation exceeds precipitation in all months except in November and December (Figure 2).

Figure 2. 20 years average of rainfall and evaporation in the Kirindi Oya.

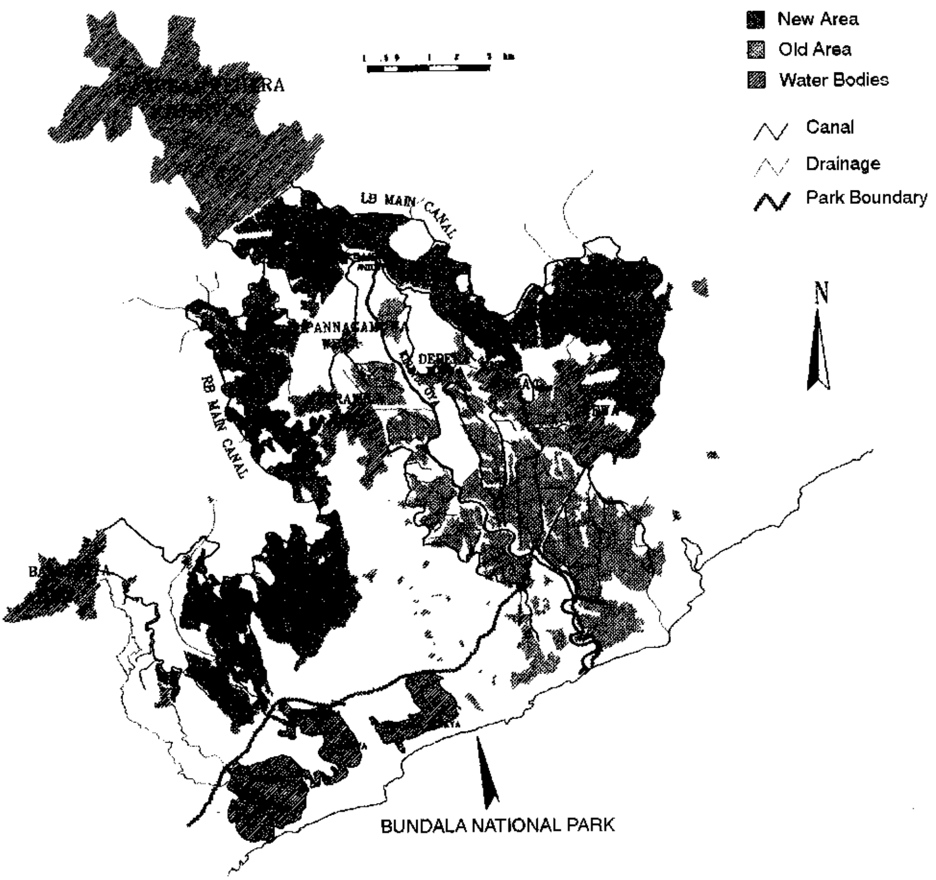


Source: Irrigation Department

The major reservoir Lunugamvehera was commissioned in 1986 providing irrigation facilities to 5,400 ha of land (new area), and 4,600 ha (old area) which already existed in the Ellegala Irrigation System (EIS) located downstream of the reservoir (Figure 3). The Lunugamvehera reservoir has a catchment area of 914 sq.km., with a gross storage capacity of 230 million cubic meter (MCM) and an active storage of 200 MCM. The Right Bank Main Canal (RBMC) of the reservoir is 32 km long ending at the Badagiriya tank, with a discharge capacity of 13 m^3/s, 19 gated cross regulators and 42 take off canals, and a command area of 3500 ha in 5 tracts. After the last regulator and takeoff at 27 km, the canal flows into a small tank, and then continues as a feeder canal to augment Badagiriya tank. The Left Bank Main Canal (LBMC) is 17 km long with a discharge capacity of 12 m^3/s, 41 offtakes and regulators, and a command area of 1900 ha in 3 tracts.

The tanks under the EIS provide irrigation water to lands under five tanks: Tissawewa (1,112 ha), Weerawila (931 ha), Yodawewa (1,322 ha), Pannegamuwa (227 ha), and Deberawewa (405 ha). There are two feeder canals from the Ellegala Anicut, the left bank feeder canal (11 km long) divides into two, a small branch feeding the Deberawewa tank and

Figure 3. Map of Kirindi Oya Irrigation & Settlement Project



the main branch feeding the Tissawewa and Yodawewa tanks. There is an outlet canal from Deberawewa that takes the spill-water to Tissawewa. The right bank feeder canal is 6.4 km long, and feeds Pannegamuwa, from which a feeder canal takes water to Weerawila.

The areas south of the left bank of the reservoir drain into the old tanks, Deberawewa, Tissawewa, and Yodawewa. Areas east of the right bank canal drain into the Weerawila and Pannegamuwa Wewa and areas south of the right bank canal drain into the Embilikala and Malala lagoons. The Embilikala lagoon is an inland lagoon with no direct outfall to the sea, while the Malala lagoon has a direct outfall to the sea and the two are connected by an incised natural canal. Drainage water from old tanks in the upper reaches (Pannegamuwa, Deberawewa and Tissawewa) flow back into the old tanks in the lower reaches (Weerawila and Yodawewa), into the Kirindi Oya river or to other outlets to the sea.

The Badagiriya tank, which is built across the adjoining Malala Ara river basin has its own independent catchment of 350 sq.km, and a storage capacity of 11.2 MCM, providing irrigation water to 850 ha of land. A total of 429 families were settled under the scheme between 1957 and 1973. The Badagiriya tank has been included in the study as it is augmented by the RBMC of the Lunugamvehera reservoir with a fixed volume of 6.2 MCM water annually, and can be considered to be within the system. The augmentation had been necessitated because the water supply to the Badagiriya tank has been reduced considerably by the construction of many small tanks upstream of Badagiriya on the Malala Ara. The drainage water of Badagiriya flows into the Malala lagoon, which is situated in the Bundala National Park.

The soils in the new area are a mixture of 75% well drained Reddish Brown Earths (*Chromic Luvisols LVx*) in the upper reaches and 25% of Solodized Solonetz (*Gleyic Solonetz Sng*) in the lower reaches. Thus soils in the new areas are more suited for non paddy crops. The soils in the old area are a mixture of 30% Alluvial soils, 40% Reddish Brown Earths (RBE) , 10% Regosols and 20% Low Humic Gley (LHG) soils and are equally suited for paddy and other crops. Tank shorelines consist of mixtures of sand, alluvial and RBE soils with shell fragments. Tank beds have a large draw down area of bare mud, which cracks when dry. Mud from some tank beds is dug up for pot and brick making.

Social background

The social composition of water users in the Kirindi Oya area reflects the old system/new settlement phases of irrigation development. Most residents in the Ellegala area have been settled in the area for generations. The project impact evaluation study (IIMI 1995) reported that 62 percent of respondents had permanent houses, and people in the Ellegalla area were more likely to have bigger houses, more consumer durables, and transport (bicycles, two and four-wheeled vehicles) then those in the new settlement areas. The homesteads are well landscaped with fruit trees and other permanent vegetation, plus gardens producing vegetables. These homesteads cover 20 percent of the agricultural land in the old irrigated areas (IIMI 1995). Most physical and social infrastructures (e.g. roads, schools) are relatively well developed.

Residents in the new irrigated areas are settlers who either acquired land owing to being displaced from old holdings, or under a government program to allocate new irrigated land to the landless in other parts of the country. Many of the latter reported that political connections in their place of origin had helped them acquire land.

However, the poorly developed physical and social infrastructure when the project began, combined with the need to develop their land and homestead sites, made life difficult for the settlers. For example, for several years the only source of drinking water was from bowser trucks that delivered water at points along the roadside. Severe droughts during the early years of the project caused further distress, and induced many families to migrate seasonally to cities or their place of origin and to diversify income sources, since livelihoods obtained from the irrigated production alone were insecure. Under the irrigation development project there has been considerable government investment in infrastructure and subsidies for housing. Employment generation and increases in literacy have been greatest in the new areas.

Average household size is 5 members, with slightly larger households (5.2 vs. 4.8) and a younger age structure in the new areas. The large majority (84 percent) of households reported a male head of household with spouse. There was approximately the same number of female headed households and male headed households without spouses.

Agriculture

Although it was planned that 50%-60% of the new area and 10%-20% of the old area would be planted with other field crops (OFCs), the majority of the area is cultivated with rice in both seasons, but OFCs are also grown in 10-20% of the area, with a larger extent grown during water short years. In the Badagiriya scheme the average area cultivated has been around 600-700 ha, mostly in maha, with yala cultivation undertaken only if water is available, which is once every one to two years. The water duty for paddy is 250 cm in the new area and 100 cm in the old area. Table 1 provides eight years' averages of cultivated areas.

Table 1. Area cultivated with rice and OFCs in Kirindi Oya Scheme (average from Maha 90 to Yala 97)

	Irrigable Area	Maha (Ave.)	Yala (Ave.)
Area Cultivated with Rice - New Area - (ha.)	5,400	3,703	1,694
Area Cultivated with Rice - Old Area - (ha.)	4,200	4,092	3,415
Total Area Cultivated with Rice (ha)	9,600	7,795	5,109
Paddy Yield (mt / ha)		4.22	4.38
Area Cultivated with OFCs (ha.)		1,240	881
Total Area Cultivated (ha.) in Kirindi Oya Scheme	9,600	9,035	5,990
Area Cultivated in Badagiriya (ha.)	850	665	333
Total Area Cultivated in Kirindi Oya & Badagiriya Schemes (ha)	10,450	9,700	6,323

Sources: ID, DA, IMD, Agrarian Service Centres

The recommended quantities of fertilizers of 150 kg/ha are applied by most farmers, but some tend to over-apply nitrogen at the expense of other elements. Pesticides and weedicides tend to be applied in excess of requirements, due to the fear of crop loss. Most rice is broadcasted due to the high cost of transplanting. Other food crops are traditionally grown in yala, the area under these crops increasing in times of limited water availability. This pattern is changing with more OFCs being grown in maha season as well. OFCs usually cultivated in the scheme are green gram, cow pea, groundnut, chillies, onions, maize, gingelly and vegetables (brinjals, snakegourd, ladies fingers, long beans, tomatoes, green leafy vegetables, bitergourd, luffa, watermelon etc.). Over the last few years, banana cultivation is more popular and is being planted in both paddy fields and in highlands closer to canals or near water sources. Over the last seven years the average area cultivated with rice was about 7,800 ha. in maha and 5100 ha. in yala. The average yield of paddy was 4.2 mt/ha in maha and 4.4 mt/ha in yala. The area cultivated with OFCs was approximately 1,200 ha. in maha and 900 ha. in yala.

It is estimated that there are between 300 - 400 agro-wells in the area, providing supplementary water for cultivating mainly OFCs and sometimes rice. A government subsidy as well as technical assistance for locating water is provided for constructing these wells.

Water rights tied to irrigated land are one of the most widely recognized forms of water rights in Sri Lanka, and is no exception in the Kirindi Oya system. Generally, farmers in the old area own their homestead and irrigated land, while settlers in the new area have been allotted management and use rights by the government. Alienation rights to land for settlers were limited: they could not legally sell or lease it, and while it could be inherited, the land could not be divided among heirs (Stanbury, 1989). In addition to irrigated land and homesteads, farmers may also have the use of chena (highland) or un-irrigated plots, which are used on a seasonal basis. Nevertheless, because of water shortages and low productivity of the system in early years, many settlers in the new area abandoned their plots, and either returned to cultivate only on a seasonal basis, or allowed someone else to cultivate their land.

In developing the Kirindi Oya Irrigation System, the government recognized the seniority of existing water rights of farmers in the old areas. Those farmers were assured that their water use would not be reduced by the project and, in fact, were able to increase their cropping intensity due to more reliable water supplies from the new reservoir. Based on this guarantee, especially in the early years, in times of drought the Ellegala (old area) lands were given priority for water, even if it meant that the new areas did not get any. The general basis for water allocation to the Old and New areas is given in Table 2. Badagiriya system, whose command area is located outside the study and project area, has a water right of 6MCM per year from the Lunugamwehera Reservoir, based on approval from the Central government Cabinet (Information from Water Resources Secretariat).

The Project Management Committee (PMC) is the main organization involved in water allocation in Kirindi Oya. This is a joint government-user group entity. In addition to water allocation decisions for irrigation, the Project Management Committee attempts to resolve other problems brought to them, particularly problems that require the assistance of one of the government agencies.

The Project Management Committee allocates water for agricultural purposes by negotiated seasonal planning. In developing the plans it is assisted by the Sub Project Commit-

Table 2. Water allocation in Kirindi Oya

	Maha season	Yala season
Old Area	Enough water to cultivate 100% command area with paddy.	Enough water to cultivate 70% command area with paddy.
New Area	2/3 command area with paddy, others are encouraged to plant other field crops. If there is sufficient rainfall they can cultivate a late paddy crop.	Areas that didn't get water for paddy during Maha have priority.

Source: Brewer, 1997.

tees for Ellegala, New Area Left Bank, New Area Right Bank, and Badagiriya. Seasonal planning is flexible in that it adjusts water allocation to water availability. According to Brewer (1997) there are two generally recognized principles underlying water allocation for irrigation:

1. Equity of water distribution (defined as ensuring that every farmer gets water in proportion to his landholding within the command area); and
2. Priority to standing crops over those not yet planted.

Within the broad framework of rights there has been considerable scope for negotiation for water allocation, particularly through the Project Management Committee's seasonal planning meetings.

Water distribution—the delivery of water to execute the water allocation plan—is the responsibility of the Irrigation Department at the reservoir and main canal levels, and farmers' organizations (FOs) below the distributary level. In addition to water distribution, FOs are responsible for maintenance of the distributary channel and field channels. If they wish to do so, FOs can take on other functions (IIMI, 1995).

Livestock

The study area is considered to be a traditional buffalo and cattle raising area and is well known for its buffalo milk based curd industry. Poultry keeping and goat rearing are also undertaken but to a lesser extent. The traditional grazing grounds of the cattle and buffalo population of the area were taken over for crop production after the construction of the Lunugamvehera reservoir. This resulted in rising conflict between farmers and herdsmen, due to the increasing incidence of crop damage by cattle which had traditionally grazed in the same area.

Currently it is estimated that there are over 50,000 cattle and buffaloes, 3,000 goats and 5,000 poultry in the study area according to the Cattle Owners Associations (COA) and the Department of Animal Production and Health (D/AP&H). The Weerawila Farm operated by the National Livestock Development Board is the biggest single farm in the study area. It is located in the catchment of the Weerewila tank and rears buffaloes (100), cattle (100), broilers (5,000), layers (900), goats (1,000), and pigs (30) in 620 ha of land. The farm requires 33 m^3 of water per day.

The increased contact between herds and fields causes crop damage and conflict between livestock and crop production. To solve this problem, three Cattle Owners' Farmer Organizations (COFO) were formed on the initiative of the Project Manager Settlement[1] in 1991. They are registered under the Agrarian Services Act as farmer organizations. These organizations work together with the Divisional Secretary to find alternative grazing for the herds. The leaders attempt to work with the FO leaders to resolve disputes due to cattle damage to crops. Representatives of COFOs also attend Project Management Committee meetings (IIMI, 1995) to discuss issues of crop damage and damage to irrigation structures by the animals

The water use rights of livestock are informal and not clearly defined. The fact that customary cattle watering places were not recognized in the development of the Kirindi Oya system is an indicator of the relatively weak water rights for livestock. Even though livestock owners are represented in the PMC, their participation in that forum does not involve water allocation decisions, and therefore does not provide them management rights.

Fisheries

Inland fisheries is undertaken in almost all the major tanks in the area. In the two smaller tanks, Pannegamuwa and Deberawewa, fishing is mainly for home consumption because the water surfaces of these tanks are almost completely covered with lotus and other vegetation. Approximately 300 families are actively involved in fishing at present. Fishing is done by groups (20 persons and 3-4 boats) or individually with single boats and two to three persons per boat. At present fishing is done mainly with gillnets. The nets are set up in the evening and taken ashore the next morning. Average fish catch ranges from 7-8 kg per boat during the low season (September- March), 15-20 kg per boat during medium yield season (April-May) and 50-70 kg per boat during the high season (June-August).

Fingerlings are introduced into the tanks once a year or once each season, depending on availability. Fingerlings are produced in the fish farms of the Department of Fisheries, fish fingerling outgrowers in their own ponds and by NGOs and other groups. Fish catch is high when the water level of the tanks go down during the dry months and fish concentrate in the shallow water. Fishing is more intensive during these months. After the rains in October-November, the fish population re-establishes from the surrounding paddy fields, the Lunugamvehera Reservoir, or through the introduction of fingerlings.

There are a variety of government, NGO, and user organizations involved in fisheries, but no coherent policy towards water use for fishing. For religious reasons[2] the government support to inland fisheries was terminated in 1989. The private sector who leased the fishery stations, NGOs and cooperative societies continued with fishing. Due to their relative lack of technical expertise and the end of the government's large subsidy program for fingerlings, boats, and other assistance, there was a large decline in tank fishery production. With the election of a new government in 1994, fisheries field stations were reopened and are providing fingerlings again. An Aquaculture Development Division has also been set up in the Ministry of Fisheries.

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[1]This task is now performed by the Divisional Secretary at Lunugamwehera.

[2]Buddhist opposition to raising fish to be killed.

Fishermen are organized in Cooperative Societies for each tank. In total there are five Fishery Cooperative Societies (FCSs) in the Kirindi Oya area. Reservoir and tank fishing rights are legally restricted to Fisheries Cooperatives (Steele *et al.* 1997). Government assistance to fishermen is channeled through these Cooperatives and they are responsible for checking if fishermen stick to the rules (e.g. size of holes in the nets).

Fishing, as a non-consumptive use, requires access to water and withdrawal of fish. These rights are regulated through the FCSs, whose members have *use* and exclusion rights. However, because they do not have a voice in the Project Management Committee for regulating water levels, fishermen do not have management rights over water.

Domestic, municipal, and industrial water

There are four water supply schemes operated by the National Water Supply and Drainage Board (NWSDB) in the study area (Table 3).

Table 3. Water supply schemes in the study area

Scheme	Source	Supply Area	Treatment	Consumption in 1996 (x 1,000m3/year)
Lunugamvehera	Lunugamvehera Reservoir	New area, Badagiriya area	Aerosion + Sedimentation+ Sand filtration + Chlorination	570
Tissamaharama/ Deberawewa	Kirindi Oya River	Tissa/Debera towns	Chlorination	247
Kirinda	Groundwater	Kirinda area	Chlorination	154
Bundala	Groundwater	Bundala area	Chlorination	51

Source: National Water Supply and Drainage Board

In 1996, the total of 1 million m^3 of treated water was consumed. Approximately 50% of it was consumed from stand posts and 25% from in-house connection, while the rest is used by schools, government institutions, police stations, hospitals, religious and commercial establishments, and hotels. The design water requirements for stand post is 45 liter/day/capita and an in-house connection varies from 140 to 185 liter/day/capita. The NWSDB estimates about 30% of loss due to leakage. The Lunugamvehera scheme is the biggest scheme in the area with the maximum capacity of the treatment plant of 230,000 m^3/month

Home garden wells are common in the old area. Survey estimates indicate that there are about 2,800 home garden wells in the study area, the majority located in the old area. Average consumption of water from wells for domestic purposes is about 40 litres per day per person. Total consumption is estimated at 1.3 MCM per annum.

Most of the domestic water supplied by the NWSDB is a fixed allocation to operate the piped water supply system that serves, especially, the new areas. When there is no irrigation going on, the Irrigation Department issues water once in fourteen days for domestic purposes. In yala 1992, water issues for irrigation were even stopped in early July to protect domestic water supply to the new areas (Brewer, 1997). This is an indicator of the priority given to domestic water supply. This led to serious conflicts with farmers in the old areas who demanded water releases for irrigation.

When the water level of the Lunugamwehera Reservoir is above dead storage level (i.e. 150 feet above MSL) the NWSDB has a water right to extract 5000m^3 of water per day. When the water level is at or below 156 feet above MSL, only the NWSDB has the right to pump water from Lunugamwehera Reservoir. The Irrigation Department is therefore required to maintain at least 6 feet of water above dead storage level in the reservoir for domestic use. Further, a water right to extract 600m^3 from two tube wells at Kirinda is granted to the NWSDB to supply the Ellegala complex. The NWSDB also has a right to extract water from Tissawewa to provide for 15 standposts and 806 households (unpublished information from Water Resources Secretariat). However, it is noteworthy that the NWSDB is not represented on the PMC.

On the users' side, standpipe committees of approximately 15 to 20 households are established under the supervision of the NWSDB to manage stand posts for piped water supply. These associations are informal, i.e., no authority is vested in them under existing legislation, although they are responsible for collecting user charges from the households who make use of the standposts.[3] It is also the responsibility of the members of the standpipe committee to safeguard the water stand, and the committee is liable for the misuse of water by the standpipe users. If the users do not stick to the rules and regulations set by the NWSDB, the water is disconnected and a re-connection fee of Rs 250 has to be paid by the committee.

These rules and regulations specify that water from the standpipes can only be used for drinking purposes. During key informant interviews and focus group discussions other uses like bathing, business use and washing clothes were reported. The users allow each other to use standpipe water for these kind of purposes because there is no other water source nearby. They also reported that priority is given to pilgrims for bathing, at standpipes as well as in canals, because of religious norms. Local norms allow for obtaining water for business or factory use only if it is a small scale enterprise and if other income generating activities are lacking.

Other

No special water rights and allocation is recorded for recreation and to wildlife and the environment. The Air Force has a water right of 2000m^3 per month from the NWSDB. As far as industrial water use is concerned, there is one factory in Kirindi Oya, a garment factory which has a water right for 1300m^3 per month from the NWSDB (they are given 8 hours supply). According to the Irrigation Department, a number of hotels have requested water, but have been denied permission to remove water from tanks and other surface sources. They therefore turn to groundwater extraction, which is less regulated (although the Irrigation Department notes that this water ultimately comes from the irrigation system). Water is not especially allocated for small scale enterprises like curd pot making and brick making. People make use of the available water, which has been allocated for other purposes like irrigation

[3]User charges for a household is Rs 11 per month

and drinking. No user groups representing the water interests of industrial or micro-enterprise water users exist.

INTERACTION OF IRRIGATION WITH OTHER WATER USES

Eventually water from the Lunugamvehera Reservoir is used by all sectors as direct supply or as return flow, or drainage [Figure 4]. Water used for domestic, livestock, and fisheries consume very small amounts when compared with the comsumption for irrigation (Table 4). However, the role of irrigation water for non-cumsumptive uses is enormous. Table 5 shows inter-relationships among different uses found in the study area, and the Annex describes those relationships. It is obvious that irrigation water interacts with most of the other uses.

Table 4. Water uses in Kirindi Oya sub-basin characterized according to Molden (1997).

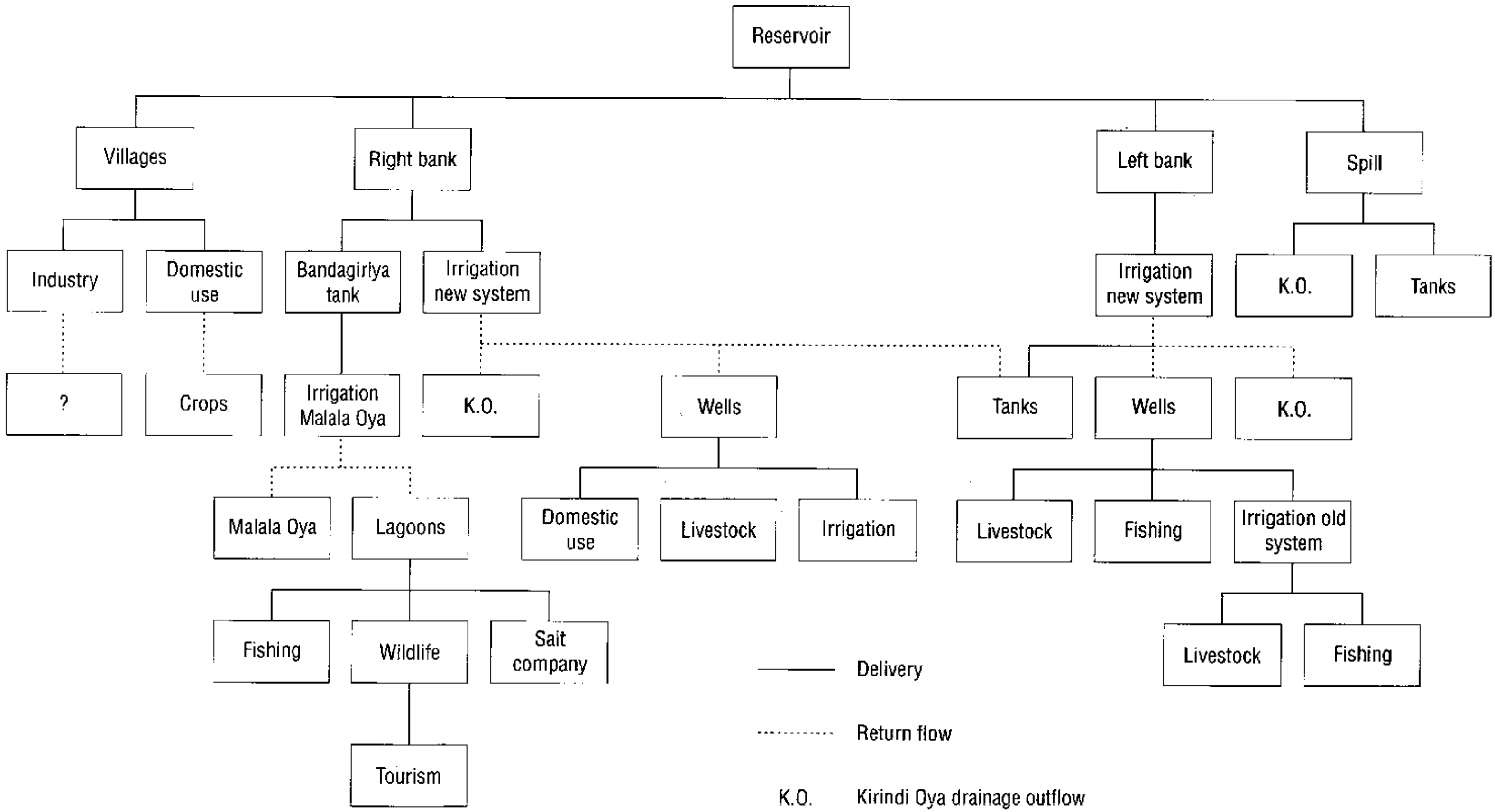
Use	Diverted to		Depleted by	
	95/96	96/97	95/96	96/97
Irrigation				
• Crops	302	156		
• E canals & tanks	–	–	109	67
• tracts 5,6,7 & Badagiriya	78	36	–	–
Forest, scrubs, grass, homestead	–	–	150	145
Livestock	0.4	0.4	–	–
Fisheries	–	–	–	–
Domestic	3.9	13.3	1.1	1.1
Industry & hotels	0.2	0.2	0.1	0.1

Table 5. Conflicts and/or competition and/or complementarity of water use

	Irrigated crop	Livestock	Fisheries	Laundry/ bathing	Drinking etc.	Home Industry	Home Garden	Environment
Irrigated crop	X							
Livestock	X/+	–						
Fisheries	X	X	–					
Laundry/ bathing	+	X	–	–				
Drinking etc.	X	–	–	X	X			
Home industry	X/+	–	–	–	X	–		
Homegarden	X/+	–	–	–	X	–	–	
Environment	X	X	–	–	–	–	–	X

X = conflicts and competition
– = no conflicts and competition
+ = complementarity

Figure 4. Seasonal water uses and inter-relationship among sectors in the Kirindi Oya scheme.



INSTITUTIONAL SETTING

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

Many of the use and management rights of different categories of water users are negotiated and mediated by a range of formal and informal organizations. Table 6 gives an overview of the range of organizations found in Kirindi Oya that relate to a type of water use.

Table 6. Government agencies and user groups representing each type of water use in Kirindi Oya

Type of water use	Government Agency	User Group
Field crops	• Irrigation Department • Irrigation Management Division • Land Commissioner Dept. • Agrarian Services Dept. • Dept. of Agriculture • Divisional Secretaries	• Farmer Organizations (distributary as well as field channel level)
Garden crops	• Agricultural Development Authority	None
Fisheries	• Aquaculture Development Division of the Ministry of Fisheries	• Fisheries Cooperative Societies
Livestock	• National Livestock Development Board • Dept. of Animal Production and Health	• Cattle Owners' Farmer Organizations
Domestic	• National Water Supply and Drainage Board • Local Govt. Authorities	• Local standpipe committees
Industry/ small scale enterprises	• National Water Supply and Drainage Board • Local Govt. Authorities	Not represented
Wildlife/ Environment	• Dept. of Wild Life Conservation • Central Environmental Authority	• international NGOs

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

The negotiations over water allocation between different uses do not just take place among user groups, or between user groups and the government, but also among government agencies. Of these, the Irrigation Department (ID) is seen as the strongest, with the greatest control over water releases. For example, the Department of Wild Life Conservation has requested changes in water flowing to the Bundala sanctuary to preserve the salinity balance in the wetlands, but does not feel it can direct the ID. Both the ID and the NWSDB feel they are responsible for allocation of domestic water.

Traditionally water allocation has been carried out by the Irrigation Department under the Irrigation Ordinance. The recent development with many sub-sectors competing for water stresses the need to create a new impartial institutional set-up to handle water sector coordination problems (Rasmussen, 1993). The Project Management Committee plays a central role in allocating water for irrigation and, to a lesser extent, for domestic uses. This joint government-user organization includes representatives from more than the irrigation sector, but at present does not take into account the full spectrum of water uses and users.

Water quality for multiple uses

It was estimated that piped water is provided to over 60% of the population in the Kirindia Oya area (IIMI, 1995), mainly to the towns, hamlets and roadside through stand posts. The people living outside of these areas have to rely on other sources for their domestic water needs. Even in the places where piped water is provided, many use water from other sources, especially for bating and laundry purposes. This is probably because the:

- NWSDB regulates consumers to use water for drinking and cooking purposes only.
- Time of water supply varies from 4 to 8 hours per day, and some posts are used by too many families during that time.
- There is a limitation to the amount of water that could be carried to houses from stand posts.

Irrigation water for domestic uses

The result of the household surveys indicated that irrigation water is an important water source for domestic use, in home industry, laundry, bathing, and recreational as well as for fisheries and livestocks. Non-irrigation water such as tap water, house connections, and wells are the preferred sources for drinking and cooking (Table 7).

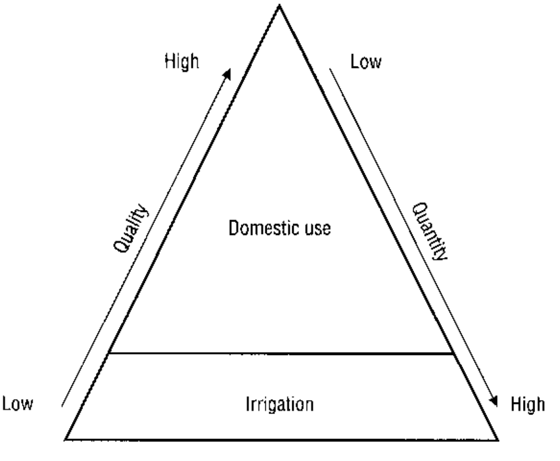
Table 7. Irrigation water as a source for different uses

Uses	No. of Respondents	Use of different sources in percentage	
		Non-irrigation water	Irrigation water
Domestic Uses			
Drinking and cooking	156	100	0
Bathing and recreation	156	54	46
Laundry	156	53	47
Washing of utensils	156	97	3
Sanitation	156	90	10
Home garden	54	87	13
Home industry	17	41	59
Agriculture			
Rice	93	8	92
Other field crops (e.g. Vegetables)	17	0	100
Shifting cultivation	30	100	0
Fisheries			
Inland fisheries	9	0	100
Livestock			
Cattle and goats	20	45	55

Water quality for multiple uses

Although the quantity of water for domestic use is a small portion of the total water depleted in an irrigated area, the quality requirement for domestic use is considered to be higher than irrigation water quality requirements (Figure 5). Satisfying the irrigation quality requirements does not mean satisfying domestic and environmental water quality requirements. For ex-

Figure 5. Comparison of quantity and quality requirements of water between domestic and irrigation purposes



ample, nutrients rich water benefits irrigated agriculture, but it is a concern for domestic use due to the health effect of nitrogen and phosphorus. Biologically contaminated water cannot be used for domestic purposes, but is not of much concern to irrigation.

In a situation like the Kirindi Oya scheme where many people are benefited either directly or indirectly from irrigation water for domestic purpose, quality and quantity of irrigation water has effects on the lives of the people as well as agriculture, livestock, fisheries, and other uses.

Besides the direct percolation of precipitation, groundwater is recharged with irrigation water from the field, tanks and canals as seepage water. During the process, soil minerals and other chemicals are dissolved in water. In the study area, groundwater level is shallow. It is often less than 1m, especially adjacent to paddy fields and canals, which fluctuate greatly during the season. Therefore, availability of shallow ground water depends on the irrigation water supply to the study area.

The water quality sampled in the study area showed that the values of colour, electrical conductivity (EC), nitrite, hardness and alkalinity exceeded maximum derirable or permissible level of the Sri Lanka water quality standard (Table 8). It indicates that the water quality for irrigation of all the reservoirs and the main canals fall into the Class 2 category, showing EC values between 0.25 - 0.75 mS/cm (Table 9). The lowest values 0.33 mS/cm was observed in the Lunugamwehera Reservoir. It was noted that EC is higher in the downstream tanks than in the upstream tanks, indicating an entry of trace elements along the watercourses. Under such conditions and with evaporation being higher than precipitation during most times of the year (Figure 5), salinity problems may occur without proper leaching and drainage. Salinity problems were reported after the construction of the Lunugamwewa Reservoir reduing the production of paddy rice (IIMI, 1995), and in the lower parts of the Yodawewa command both caused by improper drainage.

Table 8. Table water quality in the Kirindi Oya System (September 1997)

Substance		Sri Lanka Drinking Quality Standards		Water Quality in the Kirindi Oya System				
		Maximum desirable level	Maximum permissible level	Irrigation water	Kirindi Oya river	Drainage	Shallow well	Embilikala lagoon
Temperature	C			29.6	30.0	33.1	29.0	33.0
Colour	Units	5	30	7.7	7.5	7.6	7.5	8.0
Electrical Conductivity	ms/cm	0.75	35	0.70	0.89	1.67	2.28	1.80
Nitrate (as N)	mg./l	–	10	0.56	0.70	0.75	0.43	0.50
Nitrite (as N)	mg./l	–	0.1	0.13	0.01	0.12	0.01	0.06
Phosphate(as PO_4)	mg./l	–	2.0	0.18	0.23	0.15	0.38	0.17
Sulphate (as SO_4)	mg./l	200	400	36.3	50.0	45.0	72.1	N/A
Chloride (as C1)	mg./l	200	1200	93.5	78.0	320.0	416.9	380.0
Alkalinity (as $CaCo_3$)	mg./l	200	400	211.3	338.0	265.0	497.1	190.0
Hardness(as $CaCo_3$)	mg./l	250	600	192.3	240.0	400.0	650.3	450.0

Table 9. Irrigation water salinity classification

Class	EC (mS/cm)	TDS in ppm	Characteristics
C1	0.1-0.25	60-160	*Low* salinity hazard; water can be used for most crops on most soils
C2	0.25-0.75	160-480	*Moderate* salinity hazard; water can be used with moderate leaching for most crops
C3	0.75-2.25	480-1,440	*Medium-high* salinity hazard; water for use on soils with moderate/good salt tolerance, leaching is required
C4	2.25-4.00	1,440-2,560	*High* salinity hazard; water for use on well-permeable soils with salt-tolerant crops; special leaching requirements must be met
C5	4.00-6.00	2,560-3,840	*Very high* salinity hazard; water generally undesirable for irrigation; to be used only on highly permeable soils with frequent leaching and with highly soil-tolerant crops
C6	Above 6.00	Above 3,800	*Excessive* salinity hazard; water unsuitable for irrigation unless under very special conditions

Source: U.S. Salinity Laboratory in Agricultural Compendium, 1981

Regarding domestic water uses, colour exceeded the maximum desired level for all the sources, but especially for surface water. Colour influence on choice of sources may lead people to seek a colorless, but possibly unsafe, alternative source of drinking water (WHO, 1984). This may be the case in the Kirindi Oya. Water with total dissolved solids (TDS) of above 1,000 mg/l is generally not suitable for drinking. TDS of below 600 mg/l is considered to be good water while water becomes increasingly unpalatable when the concentration is greater than 1,200 mg/l (WHO, 1993). With EC levels measured in Kirindi Oya and a general relationship of TDS (mg/l) = 640 x EC (mS/cm) (ASCE, 1996), the well water is unsuitable for drinking, while the surface water is at acceptable levels. The household interviews from the study area showed that 22% of the 85 shallow wells constructed in their home gardens were not preferred for drinking, and 40% of wells used for drinking is a saline taste.

The shallow ground water also exceeded the maximum permissible level of hardness and alkalinity. The high hardness can result in scale deposition, particularly on heating and may lead to an increased incidence of urolithiasis (WHO, 1984, 1993). It was reported that the people have sticky hair when well water is used for bathing and also incidents of urolithiasis in goats in the Weerawila Farm.

Additionally, there is concern of increasing public health risks due to usage of untreated tank water (CEA, 1994). The tanks and canals are used for bathing and washing clothes by local villagers, while grazing and bathing of buffaloes and washing vehicles take place at the tank edge.

Environment and irrigation water

The Kirindi Oya irrigation scheme includes the Wirawila-Tissa Wildlife Sanctuary, and the Bundala National Park is located at its boundary. The Wirawila-Tissa Wildlife Sanctuary is a wetland and recognized as a refuge for ducks and waterbirds (CEA, 1994). The CEA (1994) reported possible effects of water in the tanks on ecology and wildlife of the sanctuary as follows:

- The negative impact on fish population and diversity caused by the reduced water level, especially in yala season
- The negative impact of water level on resident and migratory birds, when tank water dries or the water level is too high for waders, dabbling birds, etc.
- The risk of eutrophication of tanks resulting from dung and urine from livestock, discharge of effluents such as domestic drainage and sewerage seepage and drainage water from upstream, which may include agro-chemicals. Tank bed cultivation, practiced often in Badagiriya and Tissawewa tanks in the dry season may also cause agrochemical and fertilizer residues to drain into these tanks poisoning the fish population and enhancing the eutrophcation process. The process of eutrophication has already been observed in the Wirawila tank.

The hydrology in the sanctuary is directly related to the irrigation management of the Kirindi Oya scheme. The five tanks receive water through the LB main canal of the Lunugamwehra Reservoir, in addition to drainage water from Tracts 1 and 2 of the RB to Wirawila tank and from Tracts 1, 2, and 3 of the LB to Yodawewa. Therefore, the quantity and quality of water in the sanctuary is greatly influenced by irrigation practice and human activities within the Kirindi Oya Scheme.

The Bundala National Park is located at the downstream of the Kirindi Oya scheme. It covers 6,216 ha and encloses five brackish lagoons of 2,250 ha (CEA, 1993). The drainage water from the RB and the Badagiriya Irrigation Scheme flows to Embilikala and Malala lagoons, respectively. Over the past years it has become clear that the ecosystem of those two lagoons have been severely affected by drainage water coming from the Kirindi Oya scheme. RB tracts 5, 6 and 7, with a maximum cultivable area of 1,820 ha, drain into these lagoons. Water levels and salinity of the Embilikala and Malala Lagoons fluctuate due to upstream water use for irrigation purposes and drainage water from these areas. The change in salinity levels influence the population of water birds as it affects the quality and quantity of their food supply (CEA, 1993). The changes in salinity also affect, prawn farming which requires brackish water conditions and previously sustained several hundred families. Euthrophication is another problem in the lagoons. Water has a greenish color as a result of accumulation of nutrients and increase in plankton, green algae and blue green algae. The main cause being overgrazing with direct deposit of animal feces in surface water. High fertilizer runoff can add to the problem. On the other hand, an increase of drainage flow may benefit other wildlife and livestock in the national park as more fresh water becomes available.

NEED FOR INTEGRATED WATER MANAGEMENT

Because many of the water uses are non-consumptive (e.g. fishing), or require relatively small amounts of water (e.g. a curd pot making enterprise), they do not compete with other uses in terms of volume of water as long as water is relatively available. When water demand increases or water supply decreases, competition for water resources follows. This occurs especially in the yala season. For many uses, quality issues are often more important than quantity (e.g. for domestic water, fishing, or wildlife). Hence, the critical rights are not for withdrawal, but for management of the resource (and potentially for exclusion of other users that pollute).

There are limitations to the development of a management strategy in the study area, as no physical boundary exists for each use. The sources for irrigation, livestock, domestic, and environmental uses are virtually the same, and thus it is difficult to control the sources in accordance with users. The other difficulty is associated with the structure of water-related institutions at the national and project level, which does not provide for integrated water management. Water rights are not clearly defined, especially for uses other than irrigation and domestic supply. Within Kirindi Oya, the Project Management Committee has responsibility for water allocation, but despite the range of government and user organizations represented, it has not recognized the range of water uses, or the challenge of managing water to meet all needs.

The development of integrated water management strategy first requires a mutual understanding of requirements for water in all users. The Irrigation Department has an important role, as they are responsible for water delivery from the Lunugamwehera Reservoir and major tanks in the Kirindi Oya irrigation system, which has an influence on many people's well being.

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ANNEX

Irrigated crop production vs irrigated crop production

- conflict over water allocation between old and new area or between blocks in some areas
- salinity problem due to poor drainage

Irrigated crop production and livestock

- cattle damages irrigation infrastructure

Irrigated crop production and fisheries

- use of pesticides for irrigated crop cultivation which flows into the water: fish is affected
- optimizing the use of tank water for irrigation purposes may damage fishing po tential (dead storage reduces)

Irrigated crop production and drinking

- in water scarce years conflicts arise about the ultimate right of the NWSDB to hold the water in the reservoir to guarantee domestic water needs (drinking). Irrigation issues are stopped to safeguard domestic needs. This lead to big conflicts (involvement of politicians who tried to solve the conflicts) in 1992 (see Brewer) and in 1997.

Irrigated crop production and laundry/bathing

- no competition, when irrigated crop production takes place there is more water available for B&L so complementarity

Irrigated crop production and drinking

- no competition or conflict because no water for irrigated crop production is used for drinking

Irrigated crop production and home based industry/home gardens

- low amount used, complementarity (pumping of water from canals). However in some cases there can be a conflict, if, for instance, people at the head of the canal use the water for homegarden or home industries which reduces the water availability for the tail enders.

Irrigated crop production and environment

- salinity problem
- changes in brackish water conditions of coastal wetlands

Livestock and fisheries:

- livestock pollutes the water with dung and urine, which can have a negative influence on fish (euthropication)

Livestock and bathing/laundry

- livestock pollutes the water.

Livestock and environment

- conflicts over tank areas and land between cattle owners, farmer organizations and Wildlife Department

Laundry/bathing and drinking

- when there is no water available in the canals people also use tap water for laundry and bathing, this causes conflicts

Drinking and home based industries and home gardens

- when tap water is involved, people use more than they are suppose to use if they only drink it, longer queues etc.

Environment

- water which is used to leach out salts can affect the salinity level of the water in the lagoon

Multiple Uses of Irrigation Water in Hakra 6-R Distributary Command Area, Punjab, Pakistan

(Report compiled by W.A. Jehangir, IIMI, Pakistan)

INTRODUCTION

The present study documents the non agricultural uses of irrigation water by different users located in the Head, Middle and Tail reaches of Hakra 6-R Distributary in Tehsil Haroonabad, Punjab, Pakistan. The provision of water in the H-6-R Distributary depends upon a number of upstream irrigation Link Canals and Barrages as shown in Figure 1. From the left bank of the Sulemanki Headwork, Eastern Sadiqia canal originates and after covering a distance of about 74 kilometers split into Hakra Branch canal, and two other canals. The H-6-R Distributary originates from the Hakra branch canal and covers a gross command area and a canal command area of about 51,976-hectare and 42,538 hectare, respectively. The main H-6-R Distributary is about 45 kilometers long and has 283 outlets. The authorized discharge of the H-6-R Distributary is 16.65 M^3 in Kharif (season) and 15.5 M^3 in the Rabi (season). Out of the total 94 villages in H-6-R twenty-four villages (i.e. eight villages from each head, middle and tail reach of 6-R Distributary) were selected for the current study. The study investigates different sources of water, their quality as perceived by the users and the impacts of alternative sources of water in the saline areas on human and livestock health.

OBJECTIVES

The objectives of the study are to:

1. Document different uses and users of irrigation water in the study area;
2. Identify sources of water, for various non agricultural uses in the study area;
3. Document users' perceptions about quality of water for non agricultural uses;
4. Document issues related to acquiring water in the study area; and
5. Determine the incidence of water borne diseases and their impacts on human and livestock population in the study area.

DATA COLLECTION AND ANALYSIS

A multistage stratified random sampling technique was used to select the sample from the study area. At the first stage H-6-R was stratified into Head, Middle, and Tail reach on the spatial basis. At the second stage, 24 villages were randomly selected from the three reaches (figure 2). At the third stage a sample of 120 households in each reach was selected. Thus the total sample size was 360 respondents. The data were collected from both the male and female head of the households, using a structured questionnaire that was pre-tested twice in the field. The data were entered in the field in a spreadsheet format and were analyzed with statistical software.

Figure 1. Irrigation network below Sulemanki Headworks

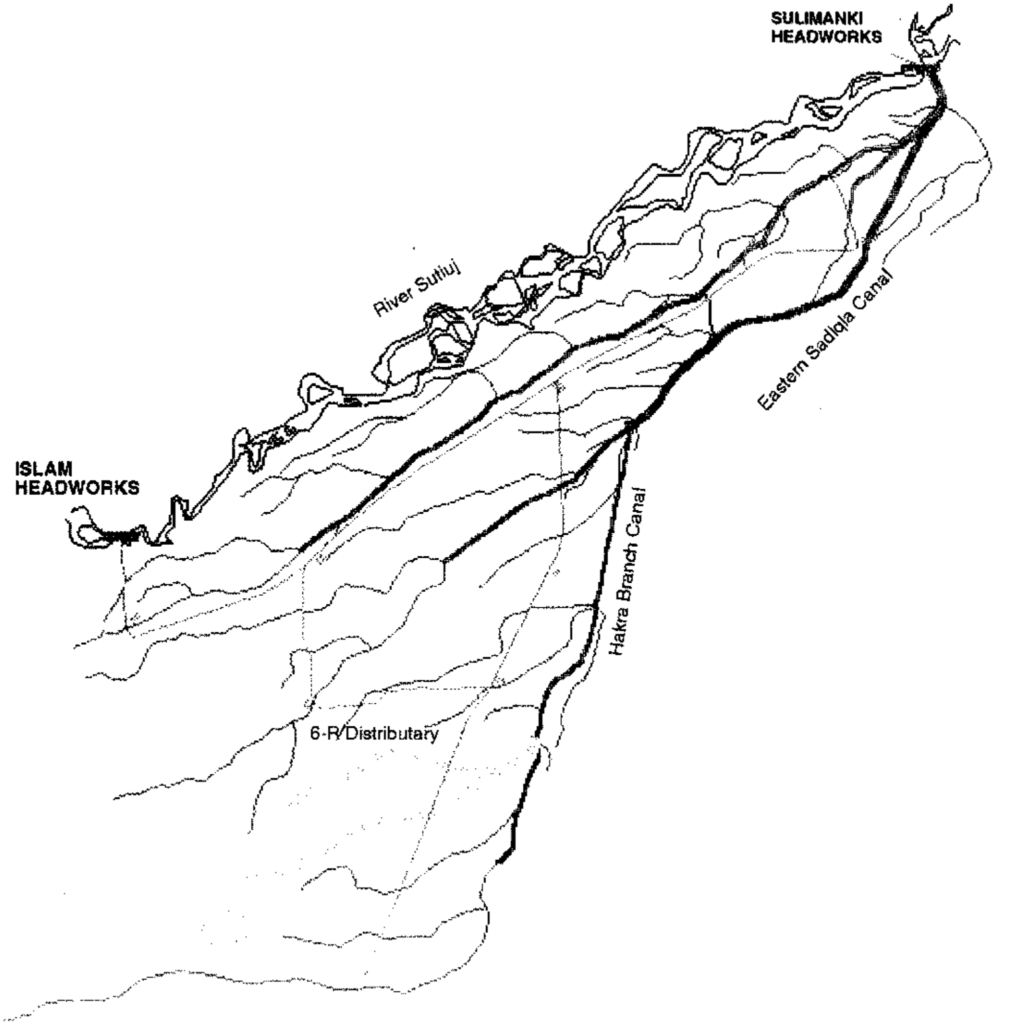


Figure 2. Location of sample villages in Hakra 6-R Distributary

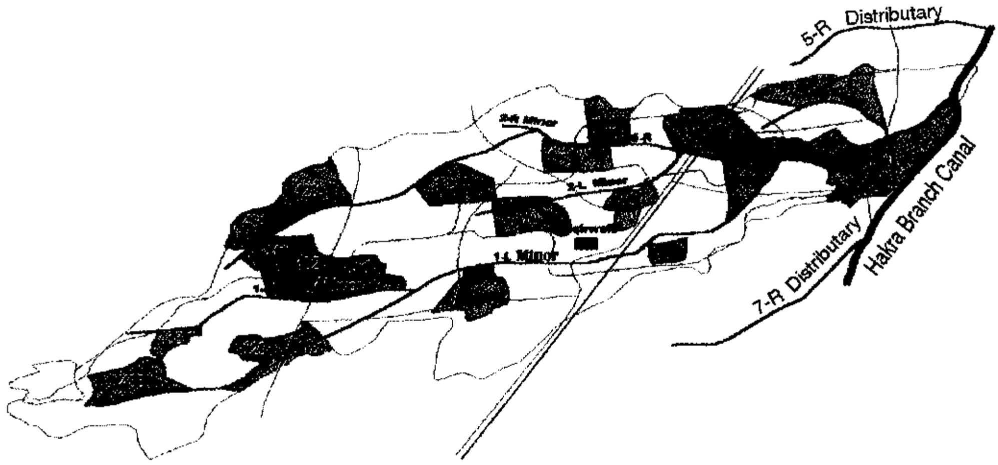
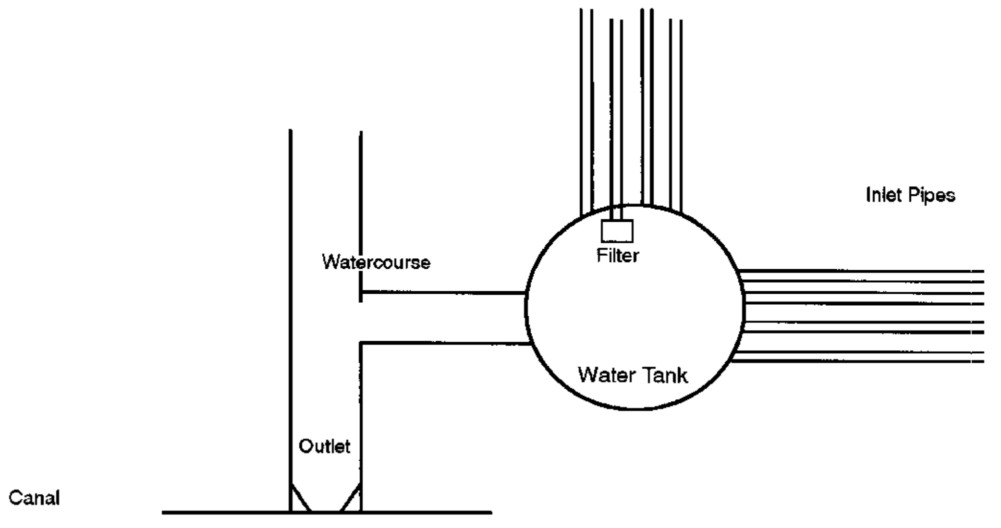


Figure 3. Layout of drinking water tank (Diggi)



RESULTS AND DISCUSSION

Non-irrigation uses of irrigation supplies in the Hakra-6-R

There are several non-irrigation uses of canal water in Hakra 6-R. These uses satisfy various household, livestock, industrial, and aquaculture needs. Apart from these, water is also used for brick making, construction, and vehicle washing activities. Except for water used for industrial production, fish farming, and brick-making, all other uses are household oriented and one or more members of the household directly benefit from that use.

Canal water allocation for non-irrigation uses

In general, two different conditions exist for water allocation. In the villages where the village water tanks (serves for human beings) and water pond (serves for the livestock needs) are connected to one of the already existing watercourses, a separate time is allocated from the irrigation roster of the watercourse for both of the tanks. The irrigation roster in the study area completes one cycle in a week (168 hours) implying that each legal user receives water once a week according to his water turn (2-5 hours). The distribution of water between the two tanks takes place on the decision of the community itself. In the other situation where the village does not fall on the route of a watercourse, a separate water supply channel runs to the village water reservoirs (Water Tank/Diggi) from the nearest canal (Figure 3). This is an exclusive watercourse but the community can only open it for a specific duration in each week.

Availability and daily consumption of water

The canal water allocation to the sample villages reveals that average per capita daily allocation of water varies between around 6 liters to 48 liters. Greater variation in allocation is evident within the villages of the head reach than that of the others reaches. The canal water feeds all the surface water sources (water tanks, water supply schemes etc.) in the area. Sometimes, the source of water is not readily accessible to the users. Only 12% of the households have access to public water supply schemes. Another 18% of the households had installed motor pumps in their homes to exploit shallow depth seepage water for meeting their daily water demand. Regarding the average daily water use for various purposes by the households, the estimates show that water tank provides around 44% of daily water use. In total, the surface water sources account for 61% of the total water supplies (water tank, water supply scheme, and canal). The only difference is that compared to the direct water use from canal, some of the supply schemes provide comparatively clean water, which is either filtered or treated with chemicals and the supply scheme runs for a specified duration daily. The water tank receives water from the canal on a weekly basis and the stilling in the tank removes silt particles from the water to some extent. The current water use meets 36% of the minimum daily water requirement. It can be asserted that the research area is extremely scarce in water resources.

Source of domestic water

About 66 percent of the households used groundwater for cooking purposes. This water was preferred because of a combination of reasons (cost, quality, accessibility, reliability, quantity, and availability).

About 72 per cent of the respondents used water from the village water tank for cleaning of households. The reasons were cost, quality, accessibility, reliability, quantity, and availability for cleaning the house with water from water tank and more specifically availability of water

About two third (65%) of the households used surface water for bathing purposes. Most of them took a bath with the water obtained from a water tank. Majority of those who used groundwater for bathing obtained it from the hand pump

For sanitation 47% of households used water from a water tank and 22% used water from the hand pump. About 12% of households used water from the water supply scheme and 14% used a motor pump.

QUALITY OF WATER

About 58 percent of the respondents regarded the quality of groundwater better as compared to that of the surface water. Most respondents believed that dust particles and a mixture of dust, salt, sanitation wastage, insects, and biological life, contaminated the surface water. About 28 percent of the respondents opined that the groundwater was contaminated with salts.

About 59 % of the users perceived surface water as the main cause of cholera, jaundice, kidney stone, malaria, typhoid, and skin diseases. On the other hand, only one respondent regarded groundwater as the main cause for diarrhea. Around 75% were consuming groundwater for drinking purposes, which also points to their perception that the surface water caused diseases more than the groundwater.

IMPACT OF NON-IRRIGATION USES ON HUMAN HEALTH

The most important water-borne diseases in the study sample were malaria (32% of total), dysentery (17%), skin diseases (13%), typhoid fever (11%), cholera (9%) and diarrhea (8%). About 12% of the respondents reported other diseases which they assumed to be related to water, i.e. jaundice, kidney stone and cancer. Higher incidence of diarrhea was recorded in the Tail and the Middle regions (12% and 9 % respectively) as compared to Head region (2.5%).

The estimates reveal that about 90 percent of the households were suffering from water-associated diseases. Total financial loss (amount spent on treatment plus wages lost) was estimated to be Rs.122,949, Rs 165,938 and 236,666 in the Head, Middle, and Tail reaches, respectively. Average treatment cost per household was worked out to be Rs.1,149, Rs. 1,536 and Rs. 2,132 in Head, Middle and Tail reaches, respectively during 1997.

Different types of treatment are used for the cure of various diseases i.e., traditional treatment from compounder, quack, and doctor depending upon income of the household, distance of doctor's clinic, acuteness of the disease, and availability of required medicines. Majority of the people got treatment from doctors for all the water borne diseases except malaria.

Only 37% of the sample households reported use of simple techniques such as boiling, chemicals (Alum or $KMnO4$) and clothe filtering. It was noted that frequency of using remedial measures particularly boiling of water and use of chemicals (mentioned above) was higher among educated households than those with less education

About 74 percent households reported use of surface water (water tank, supply scheme etc.) through applying only plain cloth filtering to avoid dust/silt, tadpoles.

IMPACT ON LIVESTOCK HEALTH

About 60 percent of the livestock held by the sample households is affected by different water associated disease like diarrhea, dysentery and foot & mouth disease. It is estimated that 48 percent of cattle, 70 percent of buffalo and 57 percent of goat population were affected by water associated diseases in 1997.

IMPACTS ON SOCIO-ECONOMIC LIFE OF STUDY POPULATION

Willingness to pay

More than 67 of the household families in the study area were willing to pay more for improved water supplies. About 79 percent of the males conceive the quality of water not good as compared to 45 percent of the female households.

More female household respondents than males were willing to pay for improved domestic water supply because mostly the burden of water fetching for domestic as well as for livestock purposes falls on women.

Aqua-culture

The government of Pakistan is providing technical as well as financial support for construction as well as operation of fish farms. Only three fish farms were reported in the area and there is the scope for aqua-culture extension in the area.

Water marketing

In middle reach villages, the average water allocation per person for other uses is 41 percent and 28 percent higher than the Head and the Tail reaches of the H-6-R Distributary, respectively. The water allocation is meant for both the water tank and the village water pond. In most of the cases the storage capacity of the water tank is enough for 10-15 days but the water turn is fixed on certain hours per week basis. The time allocated for other uses is different from village to village. As the villages in the middle reach of the distributary are reported to get more water as compared to their needs; water turn meant for other uses is sometimes sold. The water turn is sold on seasonal (rabi or kharif) or six monthly basis and is used to irrigate the fields of the highest bidder in addition to his water turn meant for irrigation purpose. There is a loose organizational set up for the auction of this surplus water allocated for other uses. The money received by this action is used for some community works belonging to that specific village.

Assessment of the Applicability of Water Quality Simulation Tools

(Report compiled by C. Scott, IIMI, Mexico)

BACKGROUND

Water use in Mexico is intensive with virtually all the major surface and groundwater sources heavily developed, particularly in the central and northern regions where irrigated agriculture predominates. At the river basin level, water reuse is common leading to relatively high overall efficiencies. The impacts on water quality are considerable, particularly considering that facilities for wastewater treatment generally handle only a fraction of the volumes generated, and that too at primary or secondary treatment levels only. For example, Mexico City generates an estimated average of 55 m^3/s of raw wastewater, of which less than 10% is treated (Naranjo, 1997). This water is used to irrigate 80,000 ha of land, primarily maize and alfalfa (CNA and IMTA, 1994). While national water quality norms exist to regulate the reuse of urban wastewater for irrigation, there appears to be less than adequate enforcement. The result is that, throughout the country, albeit on a smaller scale than Mexico City, cereal and vegetable crops are irrigated with raw wastewater.

Clearly, a wide variety of contaminants are present in urban wastewater, including pathogens, nutrients, heavy metals, and organic compounds. Defining the water quality constituents of highest priority from a management perspective is exceedingly difficult. Heavy metals and organics represent an acute problem; however, the more basic bacteriological contaminants are chronic. Biswas *et al* (1997) have stated that "While no reliable estimates are available at present, it is highly likely that economic damage to the nation from bacteriological contamination of water sources alone amounts to billions of pesos." From the perspective of national water management authorities, it has been argued that water quality is a top priority, but that finance and investment are major obstacles to dealing with the situation. There is growing awareness among the Mexican research community that water management alternatives may represent a potentially important approach to water quality remediation.

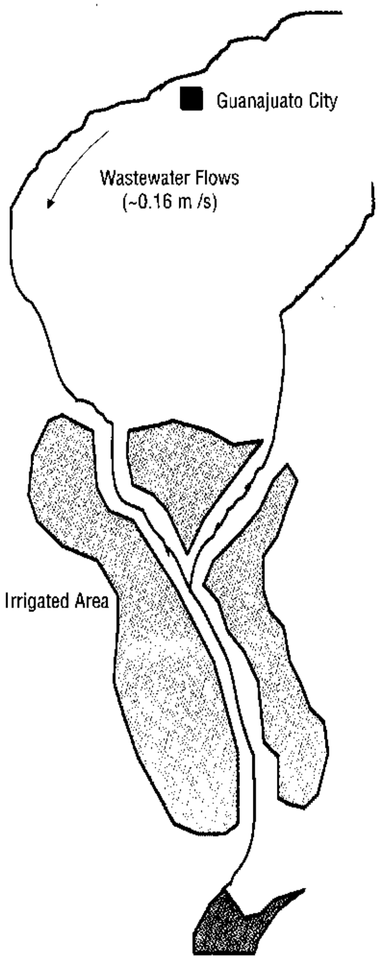
When dealing with non-conservative constituents, particularly bacteriological and nutrient contaminants, dilution, natural decay through aeration, and exposure to environmental hazards such as ultraviolet radiation in sunlight or unfavorable temperature regimes may result in attenuation. Process models exist to simulate the fate and transport of bacteriological contaminants; however, many models are "data-hungry" and require specialized data for their parameterization. Other models, for example the Interactive River-Aquifer Simulation model (IRAS) require little additional data beyond those available for flow and essential contaminant characteristics. This project assesses the applicability of IRAS to simulate bacteriological and nutrient transport in urban wastewater that is reused for irrigation.

STUDY AREA

Irrigation with wastewater is common in peri-urban areas with two basic characteristics: 1) proximity to wastewater flows, and 2) demand for irrigated produce. In Mexico, the International Irrigation Management Institute (IIMI) field office in Irapuato (Guanajuato state) has identified a research site to field test the IRAS model (see Figure 1). The City of Guanajuato has a total population of 100,000 permanent residents, in addition to a sizeable tourist population. During the dry season (November – April), an average of 160 liters per second of urban wastewater is generated, which flows down the Río Guanajuato without any treatment. This flow is intercepted by unregulated irrigation associations called "*unidades*" in small run-of-the-river systems. Throughout the state and throughout the larger Río Lerma basin, the *unidades* play a major role in the total volumes of water extracted; as a result, this project will look at the water quality implications of a widespread irrigation practice under a common management system. In the Río Guanajuato Valley, wastewater irrigation is augmented by groundwater extractions in the 15 km reach of the river below the city. At this point, the river flows into the Purísima Dam, which is the source of surface irrigation water for a 5,000 ha system operated by the La Purísima water users' association, that IIMI is collaborating with on several other studies. This project will collect necessary data and simulate the fate of contaminants in the reach of the river between Guanajuato City and Purísima Dam.

There is strong interest on the part of local collaborators, particularly the Sistema Municipal de Agua Potable y Alcantarillado de Guanajuato (SIMAPAG, Spanish for Guanajuato City Drinking Water and Sewage Board). Given that this is the state capital, SIMAPAG has also solicited the technical support of the Comisión Estatal de Agua y Saneamiento de Guanajuato (CEASG, Spanish for Guanajuato State Commission for Water and Sanitation), particularly for water quality analyses in their accredited laboratory. SIMAPAG is in the process of preparing a feasibility study for a wastewater treatment plant, likely to be submitted to the Interamerican Development Bank. As a result, there is interest in simulating the effect of different treatment levels.

Figure 1. Map of Study Area (not to scale)



OBJECTIVES

The overall goal of this project to assess the applicability of water quality simulation tools for the management of irrigation with wastewater. Specifically, the project has established the following objectives:

- Characterize current wastewater quality trends to assess implications for existing use of wastewater for semi-regulated community irrigation systems.
- Simulate instream water quality effects of alternative wastewater treatment levels and natural attentuation.
- Simulate the water quality impacts for the receiving waters in Purísima Dam.

Implementation

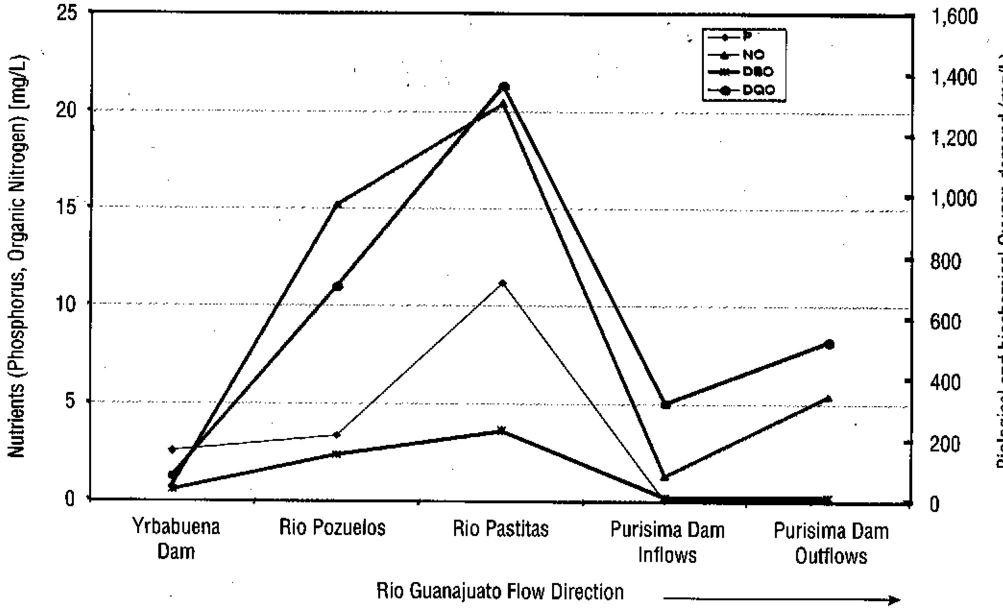
IIMI-Mexico has had three rounds of productive discussions with the collaborators, who provided us with sample water quality data presented in Figure 2. A Mexican engineer has been hired as a research assistant for the project, and is presently undertaking the fieldwork necessary for project implementation. IRAS has been applied for the simulation of water mass balances and appears to be suitable for the simulations proposed in this project. The basic project tasks are described in the implementation schedule shown in Table 1.

Table 1. Implementation schedule

Task	Jul	Aug	Sep	Oct	Nov	Dec	Jan 99	Feb	Mar	Apr	May	Jun
Identify reach to be studied.	x											
Identify data sources and define data needs.	xx	xx										
Design data collection program and identify labs for water quality analyses.			xx									
Monitor flows and collect samples for water quality analyses.				xxxx x	xxxx		xxxx	xxxx				
Link with basin simulation model.										xxx		
Identify critical contaminant "sinks" and possibilities for instream remediation.											xxxx	xxx
Final report due	x											x

As of August 1998, the project is on track for final completion as indicated.

Figure 2. Water quality data collected by project collaborator SIMAPAG



P – phosphate; NO – organic nitrogen;
DBO – biochemical oxygen demand;
DQO – chemical oxygen demand

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