Mapping Systems and Services for Multiple Uses

Kirindi Oya Irrigation Settlement Project

SRI LANKA

MASSMUS Application

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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MEASURES AND EQUIVALENTS

1 meter	=	3.28 feet
1 ha	=	2.47 acres
1 km	=	0.620 miles
1 cubic meter (m^3)	=	35.310 cubic feet
1 million acre foot (MAF)	=	1.234 Billion cubic meter (Bm^3)
1 cubic feet per second (cusec)	=	28.5 litre per second (l/s) = 0.0285 cubic meter per second (m^3/s)
TMC	=	Thousand Million Cubic Feet = 28.3 Million Cubic Meters
MCM	=	Million Cubic Meter

ABBREVIATIONS AND ACRONYMS

NRLW	Water Service of the Land and Water Development Division of FAO
APC	Agriculture Production Company
CA	Command Area
CCA	Culturable Command Area
CR	Cross regulator
DO	Direct outlet
EIS	Ellegala Irrigation System
FAO	Food and Agriculture Organization
FO	Farmer Organization
GCA	Gross Command Area
ICA	Irrigated Command Area
ITRC	Irrigation Training and Research Centre (California Polytechnic University)
KOISP	Kirindi Oya Irrigation Settlement Project
MASSCOTE	Mapping Systems and Services for Canal Operation Techniques
MASSLIS	Mapping Systems and Services for Lift Irrigation System
MASSMUS	Mapping Systems and Services for Multiple Uses
MUS	Multiple Use Services
M&E	Monitoring and Evaluation
NCA	Net Command Area (irrigable)
NIS	New Irrigation System
O&M	Operations and Maintenance
OFC	Other Field Crops
OFWM	On-Farm Water Management
RAP	Rapid Appraisal Procedure
WUA	Water Users Association

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Introduction and Background

Mapping systems and Services for Multiple Uses (MASSMUS) is a module for assessing non-crop water uses in an irrigation scheme within the general approach developed by FAO for auditing the irrigation system management called MASSCOTE (Mapping Systems and Services for Canal Operation Techniques). The need to develop specific approach to multiple uses of water in an irrigation system stemmed from an analysis of 20 irrigation schemes (Renault, 2008), which revealed that non-crop water use and multiple functions of irrigation schemes were more of a norm than an exception.

The MASSMUS module is developed in the same way as MASSCOTE, with a stepwise progressive process starting with a Rapid Appraisal Procedure (RAP), then proceeding with further steps on Capacity, Water balance, Cost and move towards the development of a vision and corresponding interventions to modernize the management set up and the operation techniques. A specific excel sheet for multiple uses (MUS) is included in the RAP Excel workbook with specific information on all the services provided by an irrigation system and the value generated by these services. This RAP sheet and the MASSMUS module need to be tested in irrigation systems which have de facto or de jure multiple functions, and where multiple uses are practiced.

The application of MASSMUS in Kirindi Oya Irrigation and Settlement Project (KOISP) Sri Lanka which is reported here is somehow singular compared to others as it has been done as a desk study. The reasons for that are manifold. The abundance of data covering multiple uses in this system (see the reference list) makes the desk study possible and relevant. In fact KOISP has been one of the first irrigation systems which have been systematically approached as a MUS project. The author of the report[1] worked in this project between 1995 and 2000 as IWMI Staff and has initiated the key studies on MUS on this project from 1996. As such KOISP has been a research and knowledge development on site laboratory from which many tools and approaches have been later on developed such as MASSCOTE and MASSMUS. It is therefore a natural thing to include KOISP in the stream of studies on Multiple Uses by reformatting all the knowledge available following the MASSMUS framework.

[1] Daniel Renault Senior Officer FAO NRLW HQ.

MASSCOTE Methodology and MASSMUS module

The generic methodology used in the study is called Mapping System and Services for Canal Operation Techniques (MASSCOTE). It is developed by the Land and Water Division (NRLW) of FAO on the basis of its experience in modernizing irrigation management in Asia (FAO, 2007). MASSCOTE integrates/complements tools such as the Rapid Appraisal Procedure (RAP) and Benchmarking to enable a complete sequence of diagnosis of external and internal performance indicators and the design of practical solutions for improved management and operation of the system.

MASSCOTE is a methodology aiming at the evaluation of current processes and performance of irrigation systems management and the development of a project for modernization of Canal Operation.

Operation is a complex task involving key activities of irrigation management which implies several aspects which have to be combined in a consistent manner. These aspects are:

- service to users
- cost of producing the services
- performance Monitoring & Evaluation
- Constraints and opportunities on Water resources
- Constraints and opportunities of the physical systems.

MASSCOTE aims to organize project development into a stepwise revolving frame including:

- mapping the system characteristics, the water context and all factors affecting management;
- delimiting manageable subunits;
- defining the strategy for service and operation for each unit;
- aggregating and consolidating the canal operation strategy at the main system level.

MASSCOTE is an iterative process based on ten successive steps, but more than one round of implementation is required in order to determine a consistent plan. Phase A focuses on baseline information, while Phase B aims at characterizing the relative size of each water service. Phase C then focuses on the vision of the scheme and the options for improving water service management.

A preliminary step (Step 0) is introduced for MASSMUS module to map multiple services provided to different users by the irrigation system (Table 1). These services could be intentional and/or official or un-intentional and/or unofficial. Till Step 6 the steps are conducted for the entire command area, whereas following steps deal with various scales of management units. The objective of step 7 is to identify homogeneous managerial units for which specific options for canal operation are further sought by running again the various steps of MASSCOTE for each unit taken separately. Then, aggregation and consolidation of the outputs are carried out at the main system level through steps 10 and 11. Thus, the methodology uses a back-and-forth or up-and-down approach for the different nested levels of management.

Table 1. The stepwise process of MASSMUS

Mapping	Phase A – baseline information
0. The water services	Initial mapping of the various services provided by the irrigation system to different users either intentionally or unintentionally.
1. The performance (RAP)	Initial rapid system diagnosis and performance assessment through the RAP. The primary objective of the RAP is to allow qualified personnel to determine systematically and quickly key indicators of the system in order to identify and prioritize modernization improvements. The second objective is to start mobilizing the energy of the actors (managers and users) for modernization. The third objective is to generate a baseline assessment, against which progress can be measured.
2. The capacity & sensitivity of the system	The assessment of the physical capacity of irrigation structures to perform their function of conveyance, control, measurement, etc. The assessment of the sensitivity of irrigation structures (offtakes and cross-regulators), identification of singular points. Mapping the sensitivity of the system.
3. The perturbations	Perturbations analysis: causes, magnitudes, frequency and options for coping.
Mapping...	Phase B – Sizing each water services
4. The share of water uses and benefits.	This step consists firstly of assessing the share of water for different uses through a comprehensive water accounting procedure and secondly determining the benefits associated to each water services (monetary, value, etc..)
5. The cost of O&M	Mapping the costs associated with current operational techniques and resulting services, disaggregating the different cost elements; cost analysis of options for various levels of services with current techniques and with improved techniques.
Mapping	Phase C – Vision of SOM & modernization of canal operation
6. The service to users	Mapping and economic analysis of the potential range of services to be provided to all users and uses of water.
7. The management units	The irrigation system and the service area should be divided into subunits (subsystems and/or unit areas for service) that are uniform and/or separate from one another with well-defined boundaries.
8. The demand for operation	Assessing the resources, opportunities and demand for improved canal operation. A spatial analysis of the entire service area, with preliminary identification of subsystem units (management, service, O&M, etc.).
9. The options for canal operation improvements / units	Identifying improvement options (service and economic feasibility) for each management unit for: (i) water management, (ii) water control, and (iii) canal operation.
10. The integration of SOM options	Integration of the preferred options at the system level, and functional cohesiveness check. Consolidation and design of an overall information management system for supporting operation.
11. A vision & a plan for modernization and M&E	Consolidating a vision for the Irrigation scheme. Finalizing a modernization strategy and progressive capacity development. Selecting/choosing/deciding/phasing the options for improvements. A plan for M&E of the project inputs and outcomes.

The MASSMUS module follows similar steps as MASSCOTE (see plate 1), with some adaptation to the specific function and constraints, inputs and outputs for MUS. The rationale for MASSMUS is a stepwise methodology to map the performance and plan management modernization. In a nutshell, the “Services Provision” is analysed for capacity *versus* the demand, sensitivity or reaction to perturbations, water sharing, the cost, the services descriptions, the demand for operation and finally the management improvements.

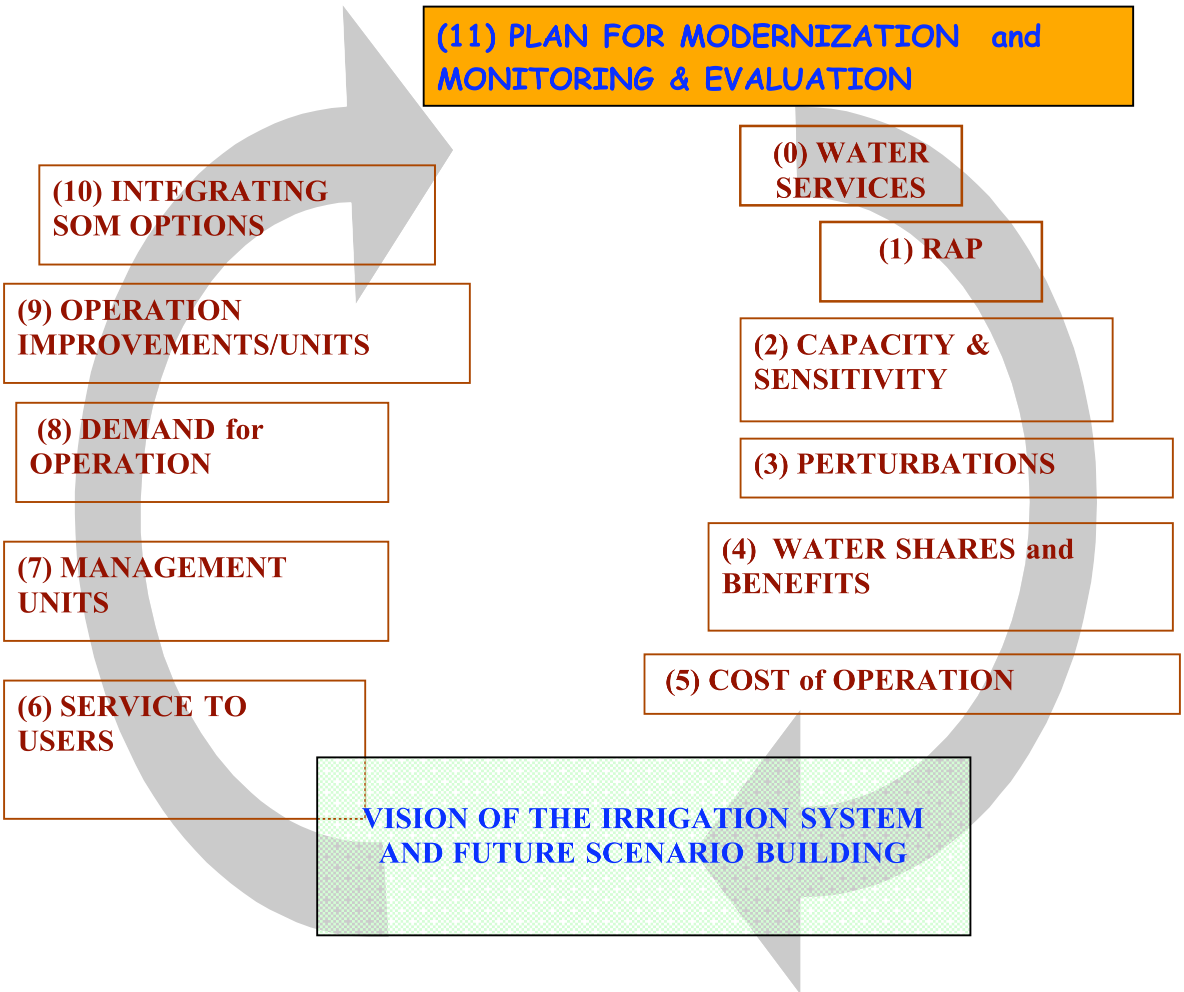

Plate 1. Stepwise MASSMUS process

Brief introduction to the Kirindi Oya Irrigation and Settlement Project (KOISP)

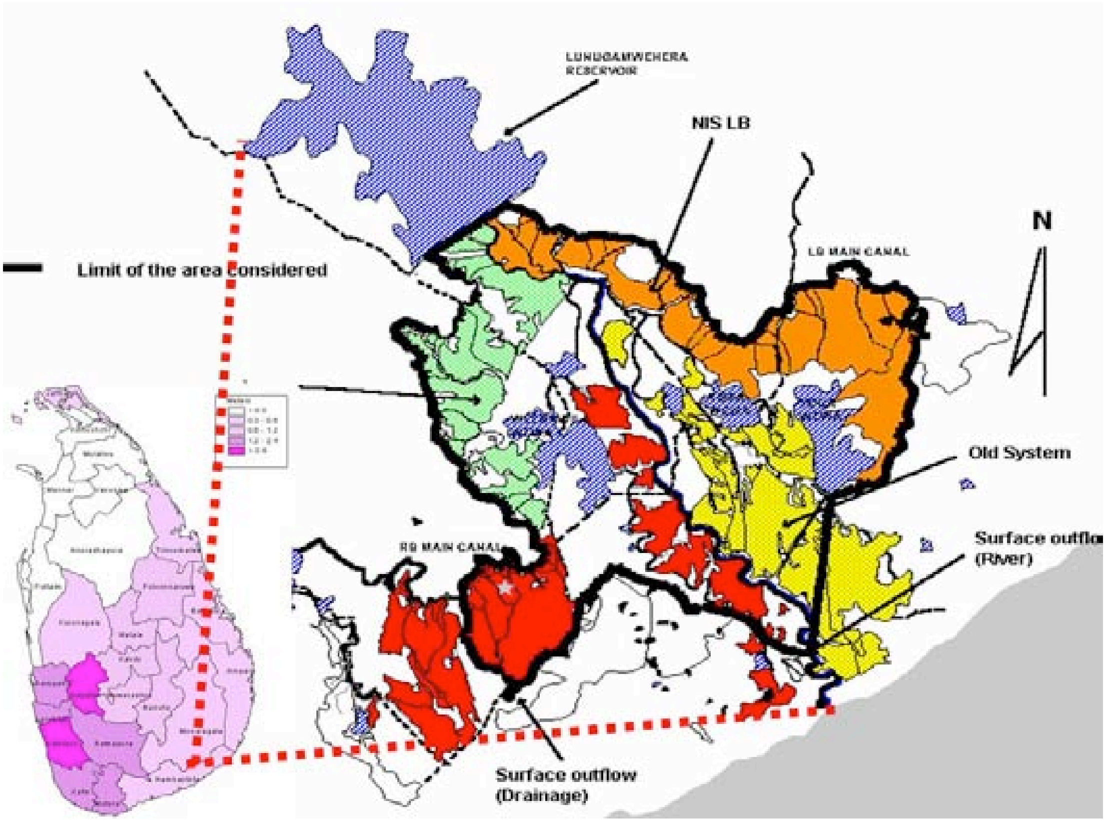

Figure 1: Map of KOISP located South East of Sri Lanka (Dry zone) with the dark line delimiting the area where water balance was performed.

The Kirindi Oya Irrigation and Settlement Project was completed in 1986 and is located in the dry zone of Sri Lanka. Average annual rainfall is 1000 mm with a dry season (Yala season) from April to October. Minimum average temperatures vary from 26 ^oC in December to 28 ^oC in April. A new reservoir Lunugamwehera is a main part of the KOISP and is meant to:

- secure supply to the old Ellegala Irrigation System (EIS), of approximately 4200 ha (EIS);
- develop new areas on the left and right banks of the Kirindi Oya river, upstream the old system, for another 5 400 ha (NIS) to serve the needs of new settlers.

The population of the GCA is estimated to be approx 100 000 habitants with 67 000 in the old areas and 33 000 in the new areas.

The project is located on the downstream part of the Kirindi Oya Basin, before the river reaches the Indian Ocean. Several peculiar features are important for the understanding of water management:

- it is a tank cascade system where drainage water is captured in downstream tanks and recycled again for irrigation. It is estimated that 66% of the new command area (NIS) is recycled in the old one (EIS);
- Excess drainage water flows into the Indian Ocean in excess of downstream of environmental needs, and the basin is considered open.

- part of the old Ellegala system, the Bundala National Park, is considered as a wetland sanctuary site of international importance (Wetland Conversation Project, 1994).
- several brackish water lagoons are seen in coastal area where ocean water is mixed with fresh drainage water. It is believed that salinity levels are dropping below the natural level because of excess irrigation drainage flows, thus endangering the natural ecosystem.

Step 0: Water Services

The Step 0 is a specific step introduced in MASSMUS module in order to start the process from the mapping of the multiple water services provided by an irrigation scheme to different users. These multiple services could be included in the design of the irrigation scheme or could be informally/unofficially emerge by practice.

The main reservoir has been designed with basically 3 purposes:

- irrigation water to secure water supply to the old area and put under irrigation the new areas.
- Domestic water for the new settlers
- Flood control for the entire area.

In practice as much as 10 different services can be found in KOISP. The classification of these services uses the one provide by the Millennium Ecosystem Assessment (MEA, 2003).

Table 2: Water services met in KOISP according to the MEA grid.

Provisioning Services	Regulating Services	Supporting services	Cultural Services
Irrigation Domestic water Water for cattle Fishery Homestead garden Industry and business (tourism)	Flood protection Environmental flows	Habitat improvements (raw materials for construction, shade, cooling effect, material for flood protection)	The social role of canal is important (people gather along the canal at afternoon end).

Box 1 . Service classes as defined by MEA (2003)

Provisioning Services, the product obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.
Regulating Services, the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.
Supporting Services, those are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.
Cultural Services, the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience as well as knowledge systems, social relations, and aesthetic values.

Irrigation: services for rice and for other crops

The agriculture has once been and still is oriented towards rice production. Two crops per year are usually practiced in Sri Lanka when water is available. Irrigation water is particularly needed during the dry season (Yala). The KOISP was initially designed to secure 200 % cropping intensity (rice) in the old Ellagala system and develop fully the new areas with the same cropping intensity of 200% with however a large introduction of Other Field Crops (OFCs) during the dry season for reducing water consumption. The initial objectives of the project are by far not reached, the new area has not been developed fully because of water shortage, and still the cropping intensity has not reached 200 %. A survey covering the period 1987-1996 (Renault, 1997) shows that irrigation intensity in the whole command area has only reached an average 138 % with a significant inequity between the two zones, 180 % in the old area and 100% in the new areas. The investigations made at that time explained the low performance was due to a loose management of water allocation and inefficient canal operation procedures leading to massive water losses through the drainage.

OFCs initially planned to be developed in the new areas were unsuccessful for many reasons despite strong efforts from the extension services (see plate 2). One of the main reasons quoted by farmers was the low irrigation intensity and the uncertainty on water allocation that prevent them from investing on OFCs. Many of the new settlers would then prefer to go for one rice crop during the wet season to secure food supply for their family and move to cities to find other jobs during the dry season.

Clearly agriculture here is demanding several types of reliable water services for different crops and somehow irrigation management were not able to answer properly.

Plate 2. A pilot area of Other Field Crops along the Right Bank Canal New area KOISP

Domestic water supply

Pipe systems have been developed in some of the new areas to deliver domestic water to some of the new hamlets but still canal water is very much used by the locals for bathing and washing (Plate 3) or even drainage water in river bed (Plate 4).

The estimation of the rate of connection to pipe water from the National Water Supply and Drainage Board (NWSDB) are 30% and 12% for the new and old areas. That is respectively 10,000 and 8,000 inhabitants connected. The service for the new area is directly generated from the main reservoir upstream the GCA, through a treatment plant. The service for the old area uses public wells. The remaining population of the GCA that is 82,000 people rely on agrowells (300-400 estimated agrowells), home garden wells (estimated 2800) and direct access to canal water or to natural streams.

Plate 3. Canal water used for bathing and washing (Right Bank canal new area)

Plate 4. Getting water from the river bed (old area)

Table 3. Access to domestic water in the CGA

Type of service	Population	Feature
Separate pipe network with treated water	18 000 habitants	Throughout the year (no shortage)
Agro-wells Homestead wells Canal water Surface streams	82 000 habitants	Critical during the dry season Low service still during canal closure (one issue of water to canals per fortnight)

The irrigation services to support domestic water services are generated by:

- direct access to canal water through stairs built on canal banks.
- recharge of shallow small aquifers and drainage flow from canal seepage and percolation from paddy fields

Fisheries

The fishing activities are quite important in the command areas including:

- fishing in tanks and reservoirs (see plate 5)
- fish in coastal lagoon
- shrimps in coastal lagoon.

It has been estimated that in the 90s some 7 percent of the households within the project area are engaged in fishing as a regular activity (Nguyen, 200x) generating an estimated gross income of 1.4 Million $ (in 1999 values).

The impact of KOISP on fishing activities has been evaluated as very positive: number of boats has been multiplied by 4 before and after the project (Nguyen, 200x). The catch per boat has also increase after the new irrigation reservoir. At least this positive outcome was straightforward till the beginning of the new millennium. Successive droughts in early 2000 have generated drastic reductions of the fishing activity and it remains to be seen how the situation has evolved since then.

Animals

The livestock in the command area has been estimated mixing data from the Department of Animal Production and Health and from Cattle Owners Associations. It is estimated that there are 77 000 cattle and buffaloes 4721 goats and 26000 poultry.

Animals are using water and agriculture land in many ways, for drinking and cooling (Plate 6) grazing along canals or on fallows lands (Plate 7).

Plate 5. Fishing activity in shallow tank of the old area

Plate 6. Water services to animals (drinking and cooling)

Plate 7. Pasturing on fallow rice fields

Perennial Vegetation

In the tropical humid countries perennial vegetation whether planted on homesteads or growing naturally in irrigated areas, contribute a lot to improve the environment as a whole. There are many benefits to the presence of perennial vegetation:

- It provides shade and coolness, and allows escape from the harsh tropical sun.
- It allows for increased bio-diversity within the ecosystem.
- Homestead forestry garden is an important source of income for farmers.

Homestead gardens

In Sri Lanka, irrigation developments have been made with the goal to provide net settlers with irrigated paddyfield of 1 ha and a homestead plot of land of approximately 0.2 ha. Established farmers in the area may possess larger areas in paddy and homestead. As in other regions such as Kerala in India, homestead gardens in Sri Lanka are of great importance for farmers to provide them with food, medicinal plants, fuelwood, a pleasant environment, and raw materials for handicrafts. One of the favourite trees planted by farmers in their forestry garden is the “Coconut palm tree” which is called in the region "the tree of life" because every part of it is used: meat, leaves, cocoshell, husk, trunk, cocowater, and roots (see Plate 8). In addition to homestead garden, natural vegetation along rivers, ditches, canals, represents another source of water depletion which has to be accounted for in water balances.

Plate 8. Typical scenery in KOISP old system paddyfield and homestead garden entirely supported by irrigation water.

In Kirindi Oya scheme, perennial vegetation has largely developed over time and now covers a great part of the area (Plates 9 and 10). It must be underlined that the importance of perennial vegetation is the result of paddy cultivation. Other crops and other irrigated techniques at the field level would have led to a completely different picture. A survey made during Yala 98 has shown that on average groundwater depth in the old system (Ellegala) varies from 1.6 meter in areas away from the river to 2.8 meters along the river. Tree roots can readily tap groundwater of this depth even in the dry season.

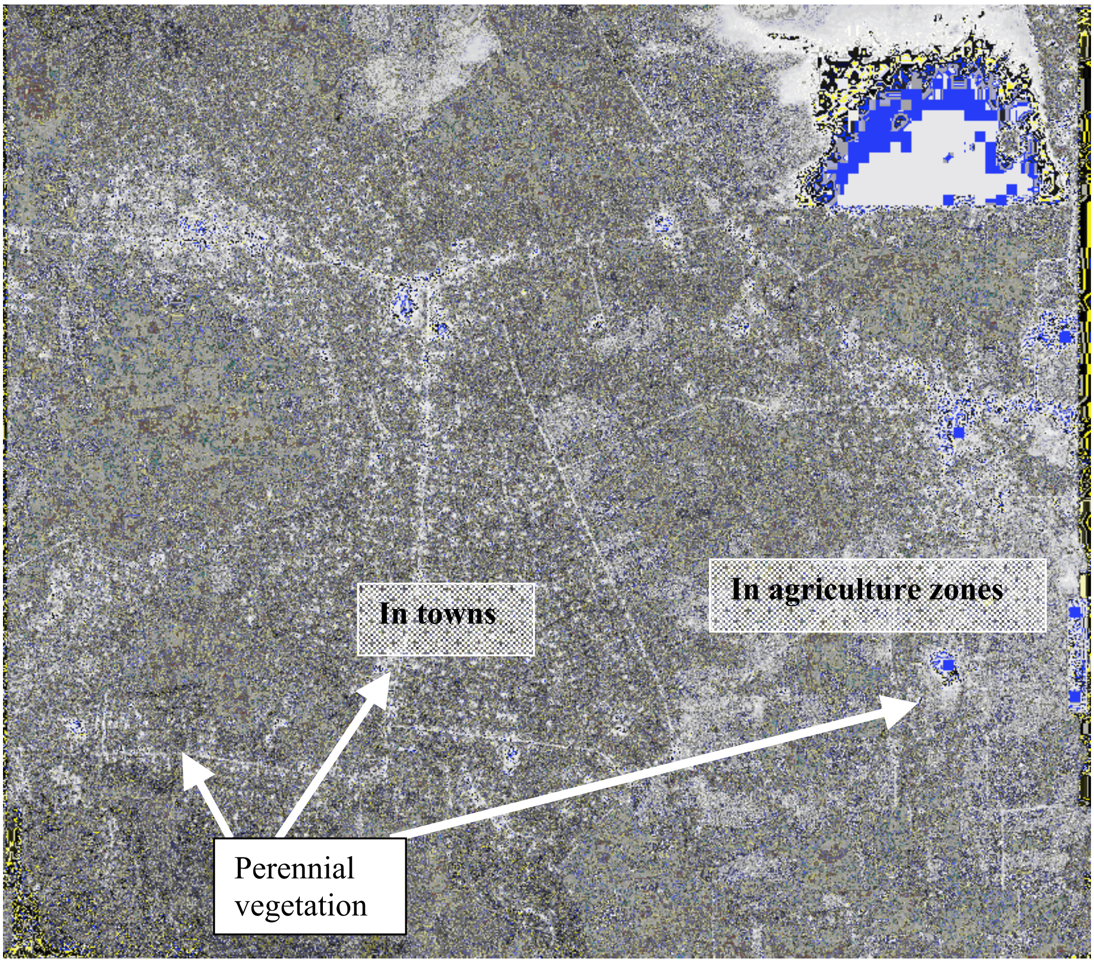

Plate 9. Aerial photograph of the old command area showing the importance of the tree coverage in Tissamarama town and between paddyfields.

Environment

The area is an important asset in terms of environment which in turn has some strong implications in the tourism activities. The Yala National Wild Life Park and the Bundala Bird Sanctuary are located within or close to the command area. In particular the old Ellagala system is considered as a wetland sanctuary of international importance for the migratory birds (Plate 11).

The coastal lagoons system is also an ecosystem which produces environmental and productive services.

These aquatic ecosystems are highly dependant on the way irrigation water is managed. Impacts can be positive or negative and one has to monitor carefully the water management in order to optimize the services. Too little water from irrigation areas can be a problem, but the reverse is also true and in fact the studies made in the late 90s show that too much freshwater from drainage is reaching the lagoons modifying the salt balance of the ecosystem.

Plate 10. Aerial view of a typical agriculture zone of EIS showing the importance of tree and rice coverage (Source Google Earth).

Plate 11. Coastal water bodies used by migratory birds.

Flood Control

Flood control was one of the original functions of KOISP through the completion of Lunugumwera reservoir, upstream of the command area. This function has been largely fulfilled, annual floods have been dramatically reduced and there are only few instances of reservoir spillage since the reservoir's completion.

Recreational and social value of the canal network

The role of water bodies for recreation e.g. swimming and boating, must be mentioned as a significant water services to the population (Plate 11). The role of the canal network as a social place is obvious throughout the command area. Every late afternoon people of all ages gathered along the banks of the major canals and besides using water interact with each other (Plate 12).

Plate 12. Recreational use of canal (RBMC KOISP)

Plate 13 Cultural/Social Services: Typical gathering along the canal late afternoon

Step 1: The Rapid Appraisal Procedure

Note: Recall that KOISP was not diagnosed as the other systems through MASSCOTE, but the analysis has been made afterwards from all documents published.

The RAP is a systematic set of procedures for diagnosing the bottlenecks and the performance and service levels within an irrigation system. It provides qualified personnel with a clear picture of where conditions must be improved and assists in prioritizing the steps for improvement. Furthermore, it also provides key internal and external indicators that can be used as benchmarks in order to compare improvements in performance once modernization plans are implemented.

The RAP was developed for large-scale surface irrigation in late 1990s by FAO together with the Irrigation Training and Research Centre (ITRC) of California Polytechnic State University (FAO, 1999). FAO has developed in 2008 a similar evaluation procedure for lift irrigation systems. This section documents the relevance and the main features of the RAP for MUS.

The basic aims of the RAP are to:

- assess the current performance and provide key indicators;
- analyse the O&M procedures;
- identify the bottlenecks and constraints in the system;
- identify options for improvements in performance.

Application of the RAP is based on a combination of field inspections, for evaluating physical system and operations; interviews with the operators, and managers, for evaluating management aspects; and data analysis, for evaluating energy balance, service indicators and physical characteristics, meetings with user's groups. The RAP is:

- systematic: conducted using clear, step-by-step procedures, well planned, and precise;
- objective: if done by different professionals, the results do not differ;
- timely and cost-effective: does not take too much time, and not too expensive;
- based on a minimum of data required for a thorough evaluation.

The physical infrastructure or hardware

The physical infrastructure or hardware (pumping station, inlet and outlets pipelines, safety structures, etc.) of an irrigation System is the major physical asset of an irrigation authority or water service provider.

Keeping the infrastructure/hardware in reasonable shape and operating it properly is the only way to achieve cost-effectiveness in producing water services. The main items to examine while appraising the physical characteristics of a system are:

- assets: storage upstream and downstream the station; pumping/lifting devices; inlet and outlet lines.
- capacities: reservoir, conveyance, pumping station/plant, other structures such as safety structures;
- maintenance levels;

- ease of operation of control structures;
- accuracy of water measurement devices;
- communication infrastructure;

The RAP exercise is supported by spreadsheets which allow entering data recorded and automatic calculation of preset indicators.

Specific Worksheet: MUS

The worksheets of the RAP-MUS are basically the same as the classical RAP ones developed for gravity fed canal with an additional worksheet (7 a.) developed for the MUS and few tables and graphs added in Sheet 1. The main elements to be filled in for each use or service are mentioned in table 4.

Table 4. Elements to be filled for each specific Use/Service of Water (Example extracted from Worksheet 7.a).

Bulk water to cities
Means of delivery/provision
Characteristic of the service: definition
Service achievement
Use of water: Consumptive *vs* non-consumptive - (fraction recycled)
Use *vs* other uses: How would you characterize the coexistence of this use with others
In case of conflict for water or in the system operation explain in few words in the cell below
Users and Governance
Service remuneration and associated taxes
Remuneration of the service by users/organisations directly to the Water Management Entity
Fee associated to the service paid by user/organisations to the State
Water use tax paid by user/organisations directly to a Water Basin Authority.
Value associated to or generated by the service

External indicators: ASSESSING the various VALUES of MUS

In a classical RAP, the external indicators (productivity) based on the gross value of the agriculture production are easy to estimate and are already included in Step 1. In MASSMUS module these indicators are discussed in more details in Step 4: water uses and benefits.

Internal Indicator 1: Number of Services

Although KOISP was designed for two additional services (domestic water and flood protection) other than providing water for crop production, it is actually providing services to many more uses. The first internal indicator of MUS is the number of services reported. In KOISP this indicator establishes itself to a very high 10 services.

Internal MUS indicator 2: how MUS is integrated by management?

A special MUS internal indicator in worksheet 5 “Project Office question” assesses the way managers see MUS. From the discussion with the managers during the 1995-2000 period this RAP internal indicator has been ranked at 2.5 on the scale from 0 to 4 (0 is lowest; 4 is highest). Table 5 below provides the criteria used fro ranking MUS integration.

Table 5. Ranking of integration of MUS in management & operation

Indicator value	**Management attitude**	**Local level operators and local practices [as seen on the field]**
0	Ignoring or denying MUS and/or its magnitude	
1	Blind eye on MUS practice by users *Manager is aware of some MUS related practices but do not consider them as part of his job.*	No intervention to reduce direct pumping from canals No particular concerns about groundwater pumping No intervention to prevent use of canal as a waste disposal.
2	Positive marginal practices to support MUS *Manager is aware of MUS services and consider positively some related practices.*	Local operators accommodate in their day to day practices the other uses of water e.g. letting unfixed leakages to drainage when water is used by downstream people/villages, letting unauthorized gate flowing into near by small tanks or drainage.
3	Integration of other services concerns into the operation *Manager knows and organises the management to serve other uses or to ensure that operation for irrigation do not penalised the other uses.*	Bulk water deliveries to villages tanks Main canal filled with water after irrigation season to provide water to people in the GCA. Local reservoirs managed to account for other uses. Minimizing period of canal maintenance.
4	Integration of Multiple Uses Services into the management and governance. *MUS is fully integrated in the Management Operation and Maintenance. Governance is made on the basis of multiple services with multiple users/stakeholders.*	Each service well defined. Users well identified, they pay for the services, they have a say on decisions on the system management.

Internal MUS indicator 3: Importance of each Use/service

The absolute and relative importance of each reported services is normally appreciated during the RAP exercise through a 0-4 ranking from the discussion with managers and among the participants.

The importance of each service should be assessed by the irrigation managers on the basis of absolute importance. They should also consider alternative sources of water available for each water use, and what would be the impact on different water if there is no canal irrigation. Both quantity and quality of water must be considered for the rating of importance.

In KOISP the current exercise is a desk study and as such it would be somehow artificial to rank the importance of the uses and services from the literature without strong feedback from the managers. Therefore this specific ranking was not carried out for KOISP.

The specific MUS sheet in RAP Excel workbook was filled using data from existing studies and published documents on KOISP.

When plotted against the number of water uses in the system (figure 2) and compared with other irrigation systems in the world, evaluated by FAO, KOISP falls in the better integrated systems (belongs to the upper half of the systems).

Step 2: System Capacity and Sensitivity.

For MUS the capacity at stakes is the one dealing with all types of service. Capacity must be seen as a physical capacity as well as time capacity. For instance irrigation canal systems are regularly (annually) off for repair and maintenance or because the irrigation season is over this results in having services to other uses reduced if not simply cut during these periods. Thus the capacity issue for MUS is also a calendar issue throughout the year. The requirement to maintain the capacity for other uses may then drastically reduce during the period of closure of the canal and thus the time allocated for repairs and maintenance.

The sensitivity in MUS is referred to the vulnerability of the specific use to the default of water service from the irrigation infrastructure, default being reduction of availability or absence of service. This goes with the lack of capacity of the system to provide services in terms of space, time, quantity and quality.

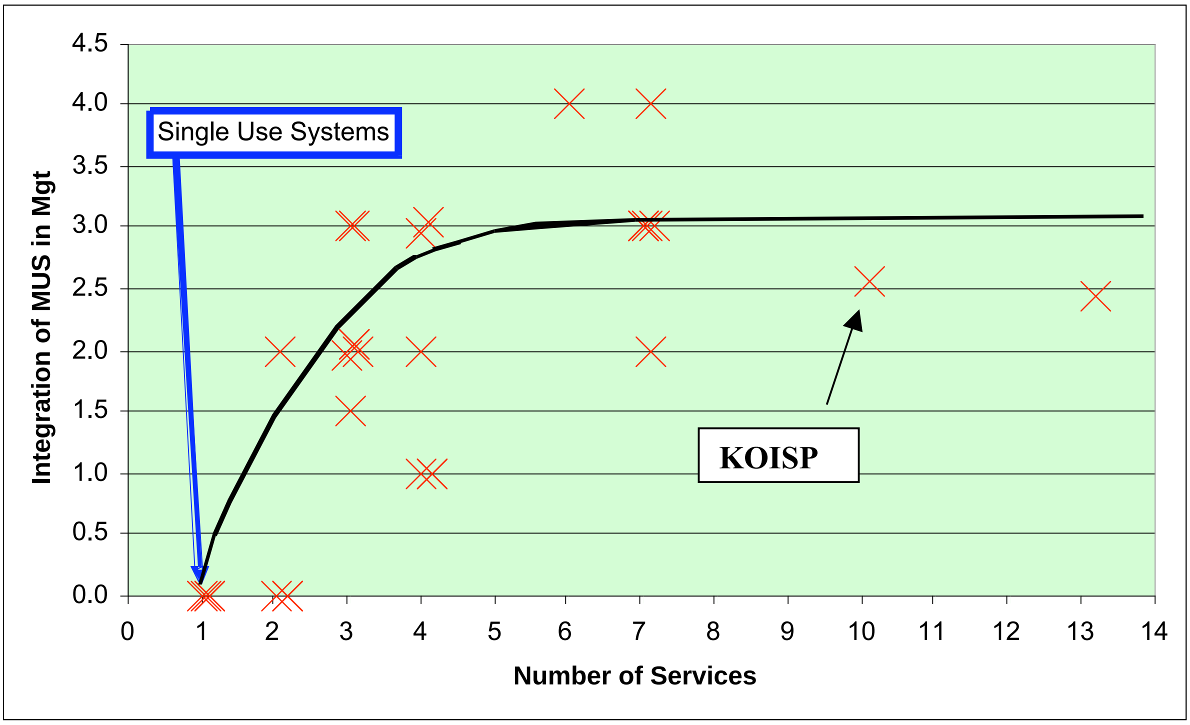

Figure 2: Degree of MUS and integration in management 30 irrigation systems audited by FAO

Sensitivity of canal structures for irrigation services

Canal system in KOISP exhibits enormous problems of sensitivity of irrigation structures. Initially designed with low sensitive characteristics for delivery, the structures have become very sensitive[2] under the effect of the raising of water level downstream the structure when managers constructed measurement weirs. Also because the canal is often run much below the full depth as it should be. The dramatic consequences are that average sensitivity of offtakes along the main canals has been raised from a low 0.4 to a very high 3. A change of water depth of 10 cm in the main canal generates a variation of 30 % of the diverted discharge at the offtakes.

The high sensitivity of offtakes has led the system to be quite unstable as the corrections made to compensate the variation of discharge are amplifying the perturbations downward. It is no surprise that the KOISP canals are difficult to operate; farmers are tempted to manipulate the gates themselves. This situation prevents managers of having a good control on water flows and water deficit downstream, waste of water elsewhere are the consequences.

[2] A sensitive offtake means that for a light change of the water level in the parent canal, the flow diverted will fluctuate a lot. Sensitive structures are difficult to operate and usually generate instability and chaos along a canal network yielding water losses here and deficits elsewhere.

Table 6: Capacity and sensitivity issues in KOISP

SERVICES	Characteristics required for the service	CAPACITY	SENSITIVITY/ Vulnerability
Irrigation services	reliable, adequate deliveries to sub-command areas flexible deliveries for OFCs	• Poor management and operation has led to low cropping intensity.	delivery structures are highly sensitive the systems is very difficult to operate
Domestic Water	Highly reliable controlled flow High quality of water	• reduced during canal closure • Management issues periodically water even when irrigation is off.	Low sensitive to deficit. High sensitive to pollution of water in the canal
Water to cattle	access to canal water supply to water ponds	• reduced a bit during canal closure	Low sensitive to water scarcity and drought. High sensitive to pollution
Homestead garden	practice of paddy cultivation near by high water table to feed root system	• No problem for groundwater recharge and percolation from adjacent fields	Low sensitive to irrigation interruption
Environment	Environmental flows	• No problem	Pollution
Fishery	Presence of water Quality of water	• Reduced during canal closure and in water scarcity period.	sensitive to long term quality sensitive to water scarcity sensitive to too much fresh water

Step 3: The Perturbations

In general terms a perturbation is defined as:

An unplanned variation of the influencing conditions that may lead to a significant change of the intermediate or ultimate delivered services.

The nature of perturbation is a function of the service specificities. It is also quite different in terms of duration: for a delivery point in irrigation, fluctuations lasting less than one hour can have serious impacts of the service delivered, whereas for groundwater recharge, only long duration of shortage can yield to a noticeable change in the aquifer.

Perturbations along the canal: one source of perturbation is the unplanned illegal operation of offtakes by farmers willing to adjust for the high discharge variation linked to the high sensitivity of the offtakes.

Table 7: Perturbation analysis in KOISP

Items	Quantity	Quality
Causes	Runoff from adjacent watersheds (canal is single bank) Sensitivity of the structures generates huge variations of discharge	• too much freshwater drained into the lagoon • quality deterioration of canal standing water when irrigation is closed in the new areas (Salt leaching was a fear in the newly developed area but it did not last)
Magnitudes	High	Important
Locations	- New areas more accented downstream of the new canals -	- New systems - Lagoons
Frequency	- quite frequent during the rainy season for runoff - always for sensitivity	- All the time
Options for copping with	- Reduce structures sensitivity and increase canal control - Stored runoff water into buffer reservoir or divert surplus into paddy fields.	- Reduce the drainage water from paddy systems - Issue water more often on canals when irrigation is closed.

Step 4: Water shares and Benefits

Water Balance

A preliminary water balance was made in 1996 as part of an evaluation study during a period of 45 days on a sub-command area of EIS (Mallet, 1996). Recorded values are displayed in Table 8, it was estimated then that perennial vegetation evaporates a similar amount of water than paddy fields.

Table 8. Water balance on part of the old EIS system command area in million cubic meters (45 days - dry season 1996)

INPUTS mcm		OUTPUTS mcm		
Irrigation issues	Rainfall	Crop evapotranspiration	Drainage	Others Perennial vegetation
11.5 95%	0.6 5%	3.8 32 %	4.8 39 %	3.5 29 %

During the 1998 calendar year, measurements have been carried out to establish a water balance within the scheme. The water accounting figures are reported in Figure 3 and Table 9, following the framework proposed by Molden (1997). Details about measurements and evaluation are given below.

The studied Gross Command Area

The water balance domain is shown in Figure 1 with the dark line delimiting the area. The domain does not completely coincide with the entire command area because of the points selected for reliable measurement. Part of the downstream left bank in the old area EIS and parts of the right bank main canal in NIS are not incorporated in the water balance. Drainage from these areas was not measured. The water balance domain is bounded by the main canals in the north and the limits of the outflows catchment areas in south, the impermeable layer of the underlying aquifer, and is taken for a one year time period (January 1rst to December 31rst 1998). The water balance domain area covers a Gross Command Area (GCA) of 25,638 hectares as measured by remote sensing image.

Uncertainty in water balance computations come from two sources. We are not certain that the downstream boundary coincides with the catchment area that drains to the measuring point. Second, there are small external watersheds which drain to the main canals which we have assumed to be negligible. Other uncertainties come with measurement errors and estimates of evaporation and evapotranspiration as described below.

Crops considered for the water balance are basically for each season:

- Rice for an area of 7619 ha
- Bananas for an area of 1000 ha.

OFCs are not limited to Bananas, but the latter is the main product and without specific data we have taken the entire OFC area as banana.

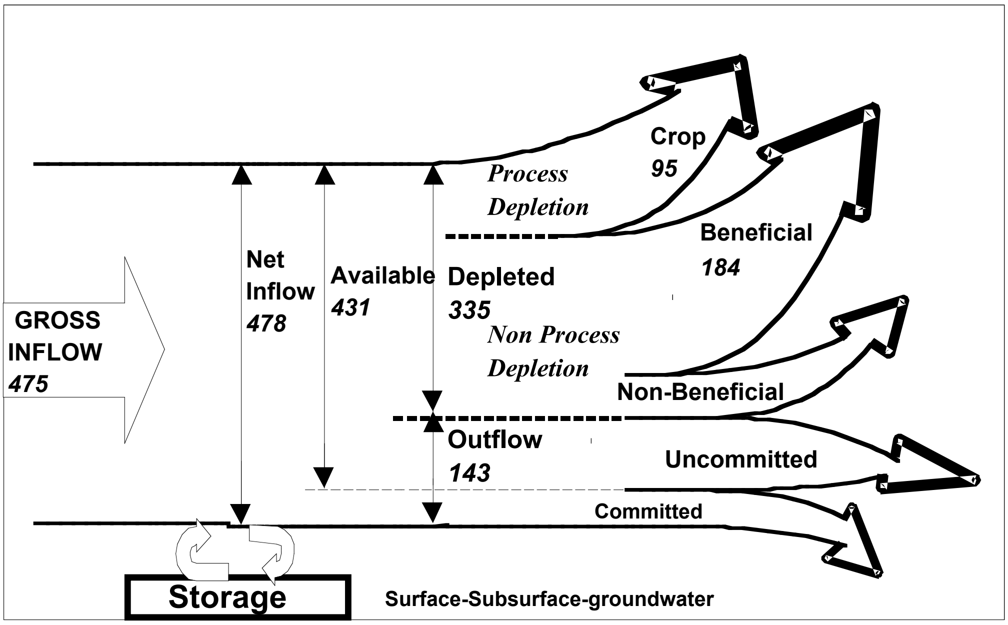

Figure 3. Water Balance in Kirindi Oya *(Figures are in mcm, million cubic meters)*

Table 9. Water balance in Kirindi Oya for 1998.

INFLOW		NET Inflow[1]	Com-mitted	Available	OUTFLOW Uncommitted	Process depletion CROP	Non-Process depletion	
Irrigation	Rain	**478**	**47**	**431**	**96**	**95**	Beneficial	Non Beneficial
245	**230**	100%	10%	90%	20%	20%	**184** 38%	**56** 12%
475							**240** 50%	

1) Inflow +storage variation

Gross Inflow
Rainfall: Rainfall is measured at three locations within the scheme. The average rainfall on the domain for 1998 was 897 mm, which is 10 % less than the long term average. The input from rainfall has been estimated for the GCA to be 230 mcm, which might be considered as a minimum given the presence of external small watersheds (not accounted for).

Irrigation: Issues from the Lunugamwehera reservoir located across the river upstream of the scheme (Figure 1) are measured twice a day. Issues accounted for in the water balance are those recorded on both left and right bank headworks. A total of 245 mcm has been issued during 1998. Thanks to heavy rains late 1997, water resources were abundant in 1998 and the irrigation intensity reached the maximum (200%). The irrigated area of the studied GCA amounts to 8619 ha.

Net Inflow:
The net inflow is the Gross inflow minus the storage variation. In the domain under consideration there are three types of storage which are surface, subsurface and groundwater. The surface storage is made of four major tanks in the old system totaling a capacity of 27.4 mcm. The storage volume has decreased between the 1rst of January and the 31st of December by an estimated volume of 2.7 mcm. The subsurface storage is the water stored within the soil matrix under irrigation. Given the fact that the area under irrigation has not changed, it is assumed that there is no subsurface storage variation between the start and the end of the year study. The storage groundwater lies for the main part in the flat alluvial plain of the old area. It is also assumed that there is no significant groundwater storage variation. December is in the middle of Maha season (wet), and groundwater is always at the highest level due to the conjunction of inputs from both rain and irrigation.

The depleted flows.
Process Depletion: Water that is depleted by intended uses is considered process depletion (Molden, 1997). Water is delivered primarily to irrigation use. Other process depletion is through the piped water system delivering water to farmers, but the amount of this entering the water balance domain is considered negligible. At times water is intentionally released in the canal for bathing, but it is assumed that this is not depleted, rather enters the groundwater system and is available for use (van Eijk, 1998).

Crop evapotranspiration has been estimated for the period of reference, using Pan Evaporation data recorded at Lunugamwehera reservoir with usual crop coefficients. For the 8619 ha irrigated within the GCA of the studied area, the crop consumption for two crops per year has been evaluated to be 95 mcm.

Non process depletion: Non-process uses are natural and other unintended uses of the water resource. Non process depletion is mainly evaporative depletion by non-crop vegetation, inter-season fallow and free surface (water bodies).

Out of the 25 638 hectares of the gross command area, only 8619 ha are irrigated. The remaining part (17019 ha) includes different types of land uses: such as water bodies (tanks), urban areas, homestead garden, forests, canals, roads, etc. Except for water bodies, this study represents the most comprehensive approach to estimating the non-process depletion. However as shown in plate 9, non paddy areas are covered to a large extent with vegetation. Therefore, it is no surprise that water consumption for this land use and for non process depletion is very high.

The water consumed by perennial vegetation has been classified into one single category: non process beneficial. However there is a need to distinguish sub-classes within the vegetation, from high dense perennial vegetation (beneficial) to shrubs (low beneficial).

In the first instance for the water balance, evaporation from fallow land and free water surfaces is categorized as non-beneficial. The amount of water evaporated from fallow lands is computed from the Pan evaporation records with a crop coefficient of 0.5. This fairly high coefficient is supported by information derived from an on-going remote sensing analysis. The total amount estimated then for the fallow period is 32 mcm, which represents an average 74 mm per month. The evaporation from water bodies (tank) has been estimated using the entire area covered by the tank at full supply level, and the pan evaporation measured at the main reservoir. The estimated amount of evaporation for the whole year is 24 mcm. Given the shallow-depth in the tanks, usual in Sri Lanka, it is assumed that evaporation do not decrease significantly with water level as lateral water transfers through the tank bed feed areas no longer under water.

In the second instance evaporation from fallow land and the presence of water in water bodies are considered as beneficial. Fallow land is used by cattle growers to feed their animals, while water bodies are benefiting to the environment and to the tourism activities.

The water consumed by perennial vegetation in the GCA has not been directly assessed, but is calculated firstly as the closure term of the water balance. As such it incorporates of course all the uncertainty attached to other terms. In a second step the perennial vegetation consumption has been estimated from a RS image during Yala 1996. No major deviation has been stated between the two approaches, as discussed below. From the closure of the water balance it is estimated that 184 mcm of water are consumed through perennial vegetation. It represents an average 1200 mm/year.

The outflows. Commited and uncommited.

The first committed outflow is for irrigation of Tracts 6 and 7 of RB NIS, and part of the left bank area in the old irrigation scheme (800ha) as both are out of the studied area. These outflows are estimated as a proportion of the total issues from the main reservoir, based on the command areas. They are 26 mcm and 21 mcm respectively. The second committed outflow is for Bundala lagoon and for sanitary requirements in the Kirindi River. It is assumed that the drainage flows which are included in the committed irrigation discharge allocated for Tracts 6 and 7 and for part of the old area will take care of it.

The uncommitted outflows from the scheme have been measured twice daily: along the Kirindi Oya River close to the mouth and the drainage from tracts 5 on RB of NIS (Figure 1). They are 28 mcm and 68 mcm respectively, therefore the total of uncommitted outflow reaches 96 mcm, a similar value to irrigated crop consumption.

Closing the water balance with Remote Sensing images

Remote sensing was used to supplement field measurement to get a more complete picture of the area. A land use map was developed using Landsat images. The same images were also used to estimate evapotranspiration for a 24 hour period. using the SEBAL model (Bastiaanssen et al, 1998). Results fully confirm the above figures.

The aerial average evapotranspiration for 24 hours (ET_{24}) was estimated on the 19 th June 95 from the Landsat image, is 1.09 MCM, whereas the average value computed for 1998 amounts to 0.92 MCM per day. These two values are fairly close, and the 18% difference can be readily explained. The average value for June is 12% greater than the yearly average. Remote sensing snapshots tends always to overestimate the average because they are usually representative of the cloudless days which have a higher evaporation value than average. June is in the middle of the Yala cultivation season, whereas the annual average include periods of fallow for which irrigation is cut off and evaporation lower than for irrigated periods. It can be easily concluded that global results from remote sensing largely confirms the figures measured on the ground. More detailed analysis has led to the computation of ET_{24} with respect to land use. Values are reported in Table 10.

Table 10. Estimated values of evapotranspiration ET 24hours for the 19^{th} June 1995 (from SEBAL model)

Land use	ET 24 hours mm
Paddy field	4.5
Water body	5.4
Homestead (perennial vegetation)	3.8
Forest (perennial vegetation)	4.1

This remote sensing assessment demonstrates clearly that perennial vegetation evapotranspiration is quite important, about 4 mm/day which is just slightly less than that of measured for paddyfield. This is also consistent with the estimation of the water consumption derived from the water balance in 1998, an average 3.2 mm/day from a total of 1187 mm. As the latter value includes direct interception, the net evapotranspiration for perennial vegetation is lower. For an interception coefficient of 15 % the net evapotranspiration in 1998 is reduced to 1052mm, i.e. 2.9 mm/day.

In RAP worksheet 1: water balance, a table (number 10) is added to provide summary of the values recorded for MUS as part of water uses and as share of the total generated value. In the basic RAP for irrigation canal, the gross value of the agriculture production is the criteria used for calculating economic productivity of land (US$/ha) and water (US$/m^3). Therefore, the same indicators (gross production value) are used for most of the other water uses in order to allow comparison among the various uses. For some uses or function of water the gross value does not seem to make sense and some other criteria have to be considered.

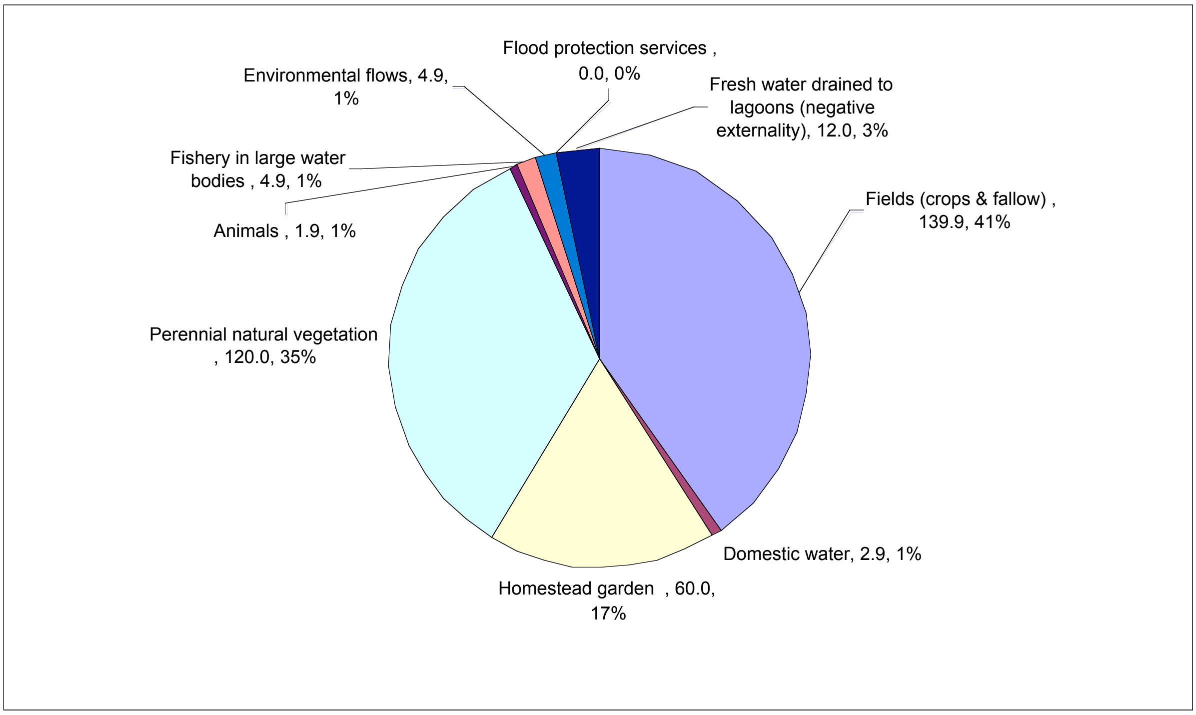

Figure 4: Water use shares in KOISP for the year 1998

Table 11. Water balance in Kirindi Oya for 1998.

INFLOW		NET Inflow [1]	Com-mitted	Available	OUTFLOW Uncommitted	Process depletion CROP	Non-Process depletion	
Irrigation	Rain						Beneficial	Non Beneficial
245	**230**	**478** 100%	**47** 10%	**431** 90%	**96** 20%	**95** 20%	**184** 38%	**56** 12%
475							**240** 50%	

1) Inflow +storage variation

Impact of perennial vegetation on the water balance

Perennial vegetation has two major effects on the water balance:

- reduction of the contribution of rainfall;
- increase in evaporative depletion of water resources within the irrigated area

It is well known now that perennial vegetation reduces the rainfall contribution to run-off because of interception. Part of the rainfall is intercepted by the canopy, evaporates directly without reaching the ground. Values of interception coefficient (percentage of rain that is evaporated by the process of interception) can be found in literature, although some discrepancies can be found between authors. Basically the interception coefficient varies with the density of vegetation and with the regime of rainfall. Interception in tropical areas is usually less than in temperate climates. For the latter, frequent and low intense rains can lead to values as high as 40 % as reported by Calder (1993; 1998). For tropical forests, reported values are 13 % for Amazonia to 21 % in Indonesia (Calder, 1993), 17 % in lowland rainforest of Malaysia to 20 % in the Philipinnes (Bruijnzeel L.A.S., 1997).

Balek (1977) cited in Radersma and de Ridder (1996), estimated that 70-80% of precipitation reaches the soil below rainforests (20 to 30 % of interception).

Tropical perennial vegetation transpires on a continuous basis throughout the year. Because roots can tap groundwater, transpiration is at full level during most of the year. Therefore it was hypothesized that consumption of water from perennial vegetation in irrigated areas might be high in terms of volume per unit area.
The source of water for perennial vegetation is from rainwater and indirectly or directly from irrigation supplies. Irrigation supplies and rainwater percolating past the root zone enters a shallow groundwater system where it can be tapped by tree roots. Part of this water would have re-entered the drainage system and been available for crop evapotranspiration, or would flow out to the Indian Ocean.

Share of benefits per services

The estimation of the benefits per service is obviously an uneasy undertaking as data are missing and rough assumptions have to be made. Although we believe that it won't change the overall assessment expressed below, different assumptions and units used may significantly influence the shares of benefits. The MASSMUS approach is rapid and cannot be taken as accurate, further studies need to be carried out to yield more precise knowledge of the water services benefits.

The main conclusion is that in KOISP 3 services are contributing to almost 90 % of the annual estimated benefit of 42.7 Millions $:

- crops for 44 % 18.7 M$ [14.3 M$ from rice 4.3. M$ from OFCs)
- animals for 25 % 10.5 M$
- homestead garden for 18 % 7.86 M$.

Then the remaining benefit is shared by 5 services coming with a low share of between 2 % and 3.3. % each:

- Fishery (3.3.%)
- Flood protection (2.5 %)
- Perennial natural vegetation (2.3 %)
- Domestic water (2.1 %)
- Tourism (2%)

Again different assumptions in the computation might generate some changes but it won't modify the order of magnitude. Table 12 displays the units used assumptions taken and ratio included for the estimation, so readers can also adjust the picture if they have more accurate estimates of the benefits.

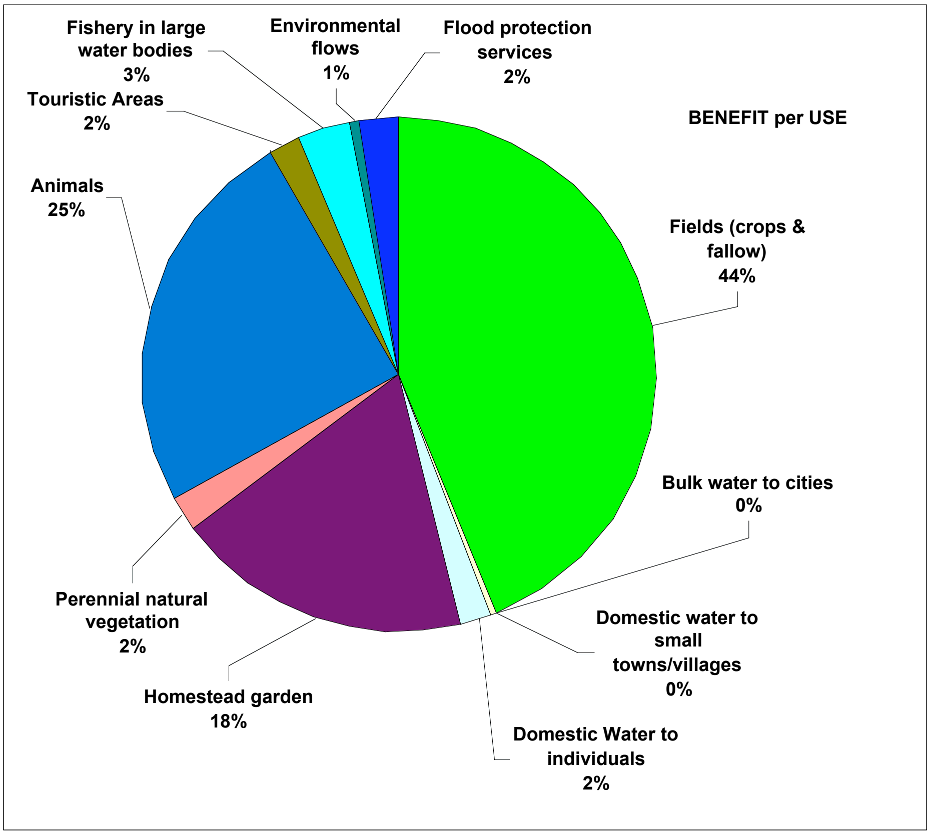

Figure 5. Share of benefits KOISP

Table 12. Units and values used to estimate the share of benefits per water services

	Quantum Unit	Water share unit	Benefit unit
Crops	Yield	Evapotranspiration	farm gate price
Animals	Head number	0.05 ; 2.5 and 7 m3/head/annual respectively for small medium and big size.	farm gate price
Homestead garden	Area	Evapotranspiration	Estimated benefit per area 0.15 $ m2/year (*)
Domestic water	Population	0.06 m3/capita/day	ratio of 10$/year/capita
Fisheries	Tons harvested	20 % of the evaporation of water bodies	Gross product surveyed (Renwick, 2001; Nguyen, 2006)
Flood protection	Homestead and cropped area	No	Homestead Asset savings plus standing crop protection:
Tourism	Jobs	20 % of the evaporation of water bodies	3 $/job/day
Environment		20 % of the evaporation of water bodies	

(*) The importance of homestead garden in such irrigated command area has been confirmed by further studies in near by watershed (Molle and Renwick, 2005). The productivity of 0.40 ha of common homestead garden in Uda Walawe Irrigation project is

estimated to reach US$ 250 per year for fruit to which some US$ 200 should be added for timber.

Water productivity

The champion of the productivity in KOISP (see Figure 6) is obviously the animal sector with more than 5 $ per m3 of water consumed. Second come the fisheries and domestic water at about 0.3 $/m3. Then crop, homestead with 0.13 $/m3.

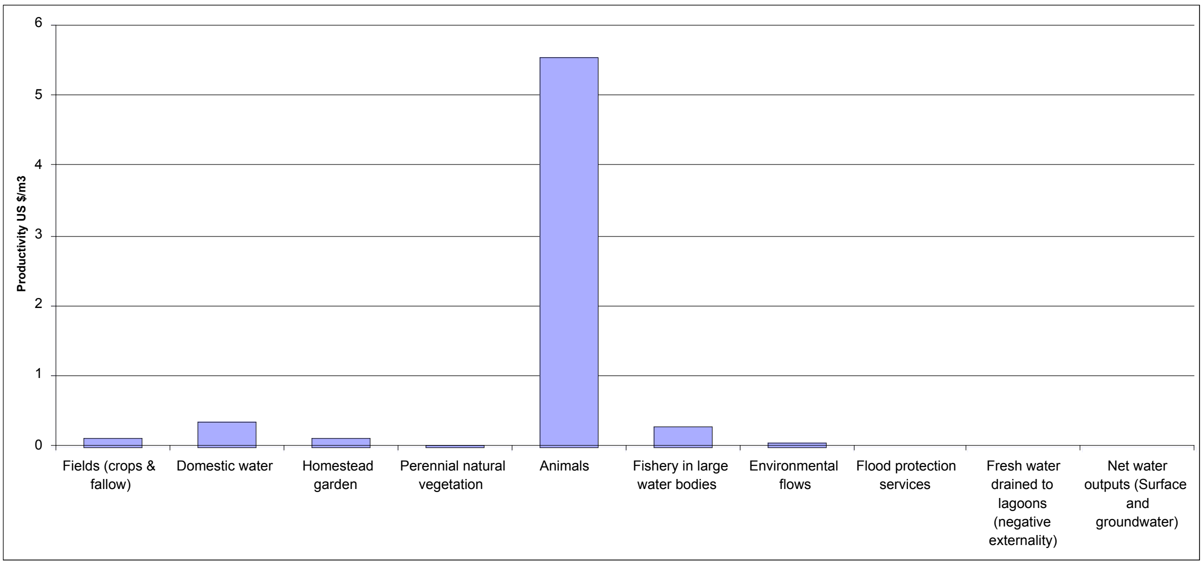

Figure 6 Water productivity in KOISP

The following steps of MASSMUS

The following steps of MASSMUS concerned the cost of operation, the service to users, the management units, the demand for operation the improvements and the consolidation of the management modernization. These steps required to return on the filed and cannot be performed as a desk study. Thus they are not addressed in this report.

Concluding Remarks and the way forward

KOISP is clearly a diversified MUS system, where irrigation water to crop and values generated by crops is not reaching 50 %. But that is not exceptional as seen in figure 7, 3 out 5 systems are having agriculture counting for no more than 50%.

Animal production (cattle, poultry or aquaculture) is important in KOISP. It seems a common feature in rural areas: 4 systems out 5 of the sample shown in figure 7. One of the specific characteristic of KOISP compared to other MUS system is the importance of perennial vegetation.

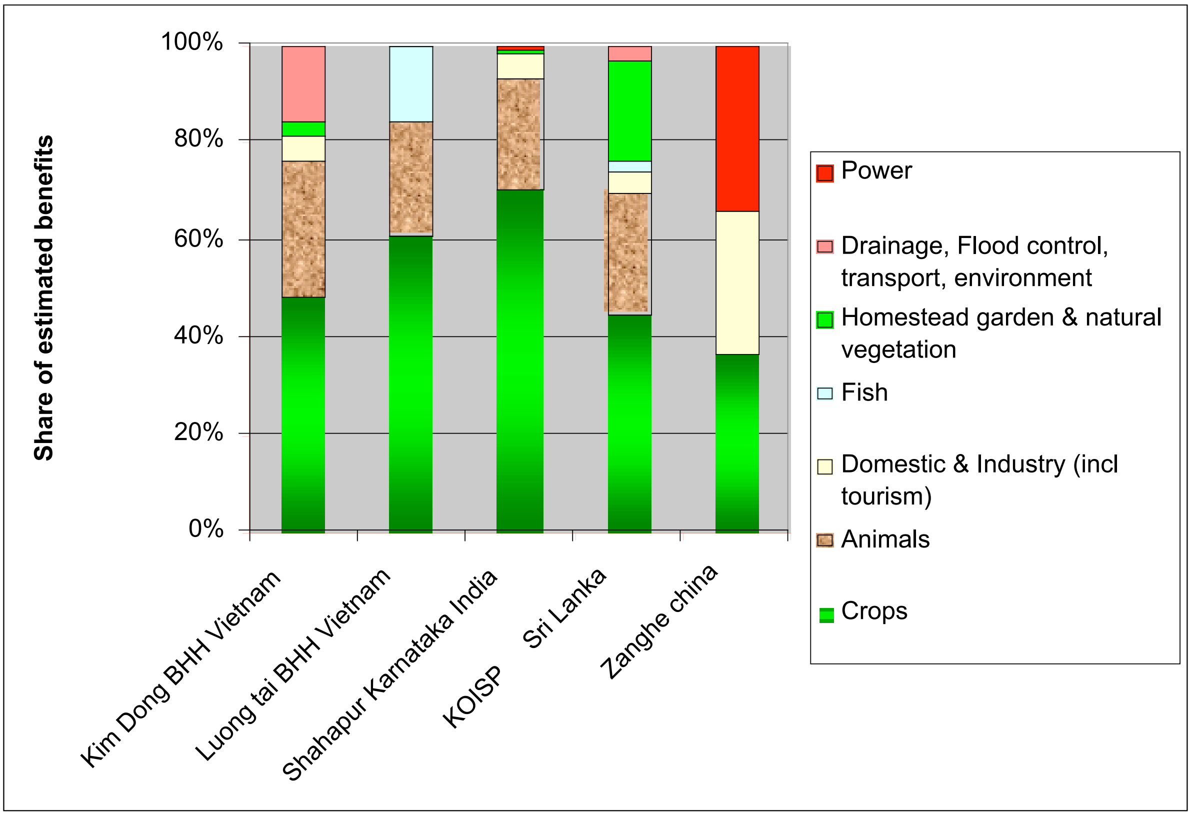

Figure 7. Share of benefits for some MUS systems.

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