Mapping Systems and Service for Multiple Uses

in

Shahapur Branch Canal

UPPER KRISHNA PROJECT–KJBNL - KARNATAKA - INDIA

MASSMUS APPLICATION

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2010

CURRENCY EQUIVALENTS

Currency Unit = Indian Rupee (Rs)
US$1.0 = Rs 45.34

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
CA	Command Area
CCA	Culturable Command Area
CR	Cross regulator
DO	Direct outlet
FAO	Food and Agriculture Organization
FO	Farmer Organization
GCA	Gross Command Area
ICA	Irrigated Command Area
IBC	Indi Branch Canal
ILIS	Indi Lift irrigation System
ITRC	Irrigation Training and Research Centre (California Polytechnic University)
JBC	Jewargi Branch Canal
JMP	Joint Monitoring Program (WHO-UNICEF)
KJBNL	Krishna Bhagya Jala Nigam Limited
LMA	Local Management Agency
LSM	Local System management
MAF	Million Acre Feet
MASSCOTE	MApping Systems and Services for Canal Operation Techniques
MASSLIS	Mapping System and Service for Lift Irrigation System
MASSMUS	Mapping System and Service for Multiple Uses & Services
MBC	Mudbal Branch Canal
M&E	Monitoring and Evaluation
NCA	Net Command Area (irrigable)
NLBC	Naryanpur Left Bank Canal
NRBC	Naryanpur Right Bank Canal
O&M	Operations and Maintenance
OFWM	On-Farm Water Management
RAP	Rapid Appraisal Procedure
SBC	Shahapur Branch Canal
UNICEF	United Nation Children Fund
WHO	World Health Organisation
WUA	Water Users Association

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 the 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 proceed 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. Shahapur Branch Canal of Upper Krishna project was selected for MASSMUS testing.

The MASSMUS application presented here has been initialized through a MASSCOTE training workshop in Karnataka for engineers and managers from the KJBNL focussing on Upper Krishna Project from 31st January to 10th February 2009. The contributions of participants made during the working group sessions at this workshop have been largely included in this report under the supervision of the supporting FAO team composed of Daniel Renault (NRLW-HQ) and PS Rao (FAO Delhi) as well as resource staff from KNNL Mrs Shukumar, Mahesh, Murley, Kulkarny and Mohanar and from KBJNL Mr. Murley.

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 scale 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 O&M cost to produce the services	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 Users and the service to users	Mapping the user's representatives that should be involved in the stakeholder process. 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.

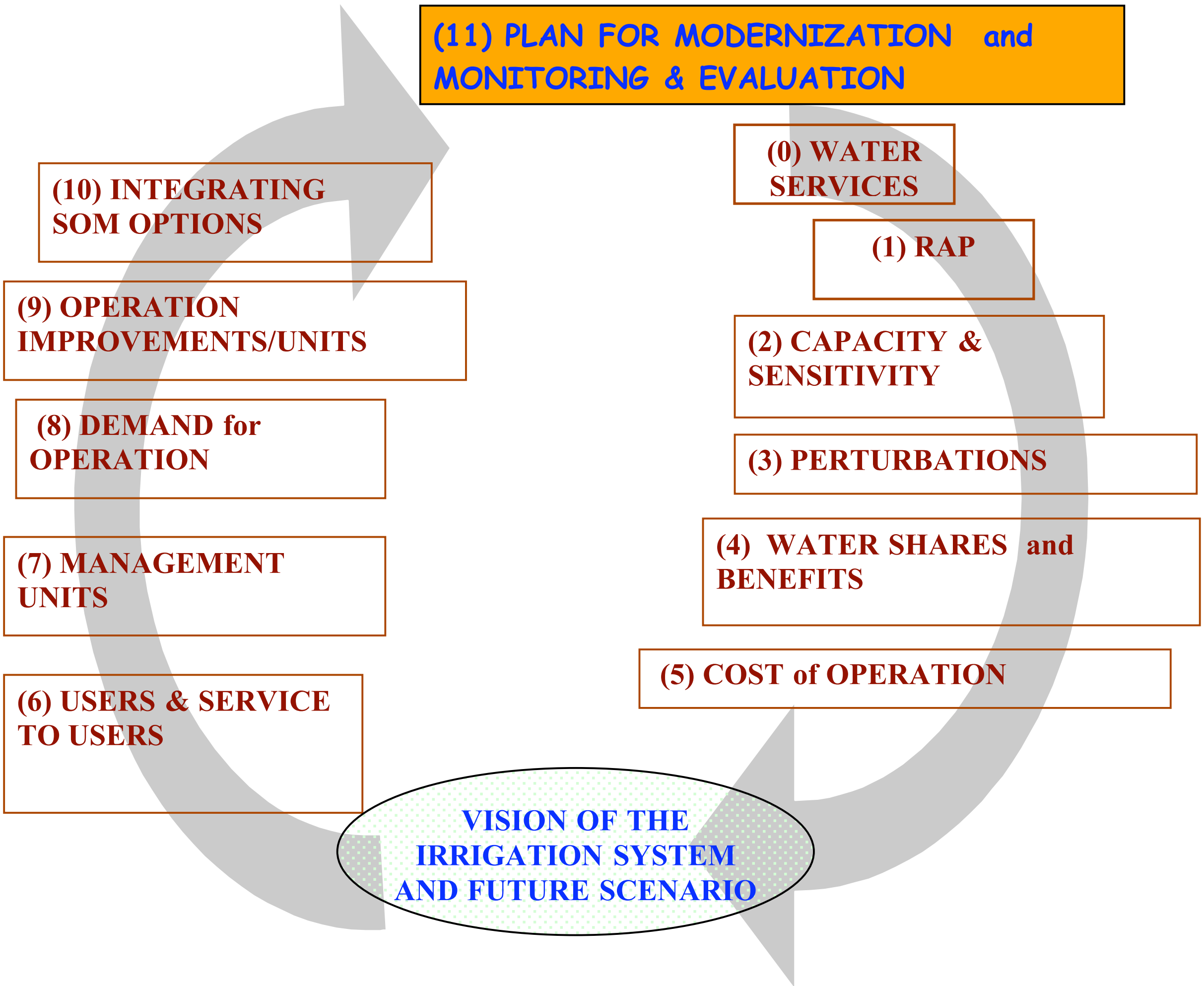

Plate 1. Stepwise MASSMUS process

Introduction of the Shahapur Branch Canal (SBC) of the Upper Krishna Project Systems

The Shahapur Branch Canal SBC is one of the command areas developed under the Upper Krishna irrigation systems using water from the Naryanpur reservoir located downstream part of the Upper Krishna in the state of Karnataka, India. A total of 8 systems have been built since 2003, fed by the Naryanpur reservoir, totalling a net command area of 513 000 ha for a GCA of 601 000 hectares (Figure. 1). The systems are built and managed under the authority of Krishna Bhagya Jala Nigam Limited (KBJNL), one of the 3 major irrigation corporate of the State. The subsystems are listed in table 2.

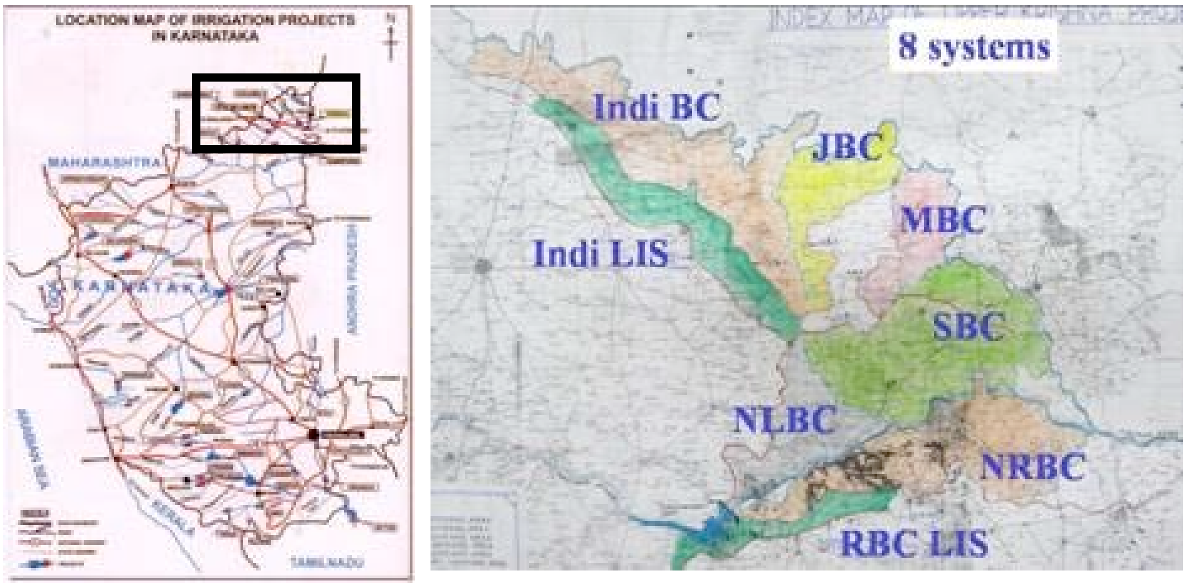

Figure 1. Location and layout of the 8 systems of the Upper Krishna Naryanpur Complex in Karnataka - India .

Table 2. Upper Krishna Irrigation Systems

Name of subsystem	ICA hectares
Naryanpur Right Bank Canal NRBC	84000
Rampur Lift irrigation System RLIS	20235
Naryanpur Left Bank Canal NLBC	47223
Indi Lift irrigation System ILIS	63076
Indi Branch Canal IBC	131260
Shahapur Branch Canal SBC	122120
Mudbal Branch Canal MBC	51000
Jewargi Branch Canal JBC	57098

The 8 systems have been investigated using the MASSCOTE methodology (see MASSCOTE application report).

MASSMUS application in Shahapur Right Branch Canal

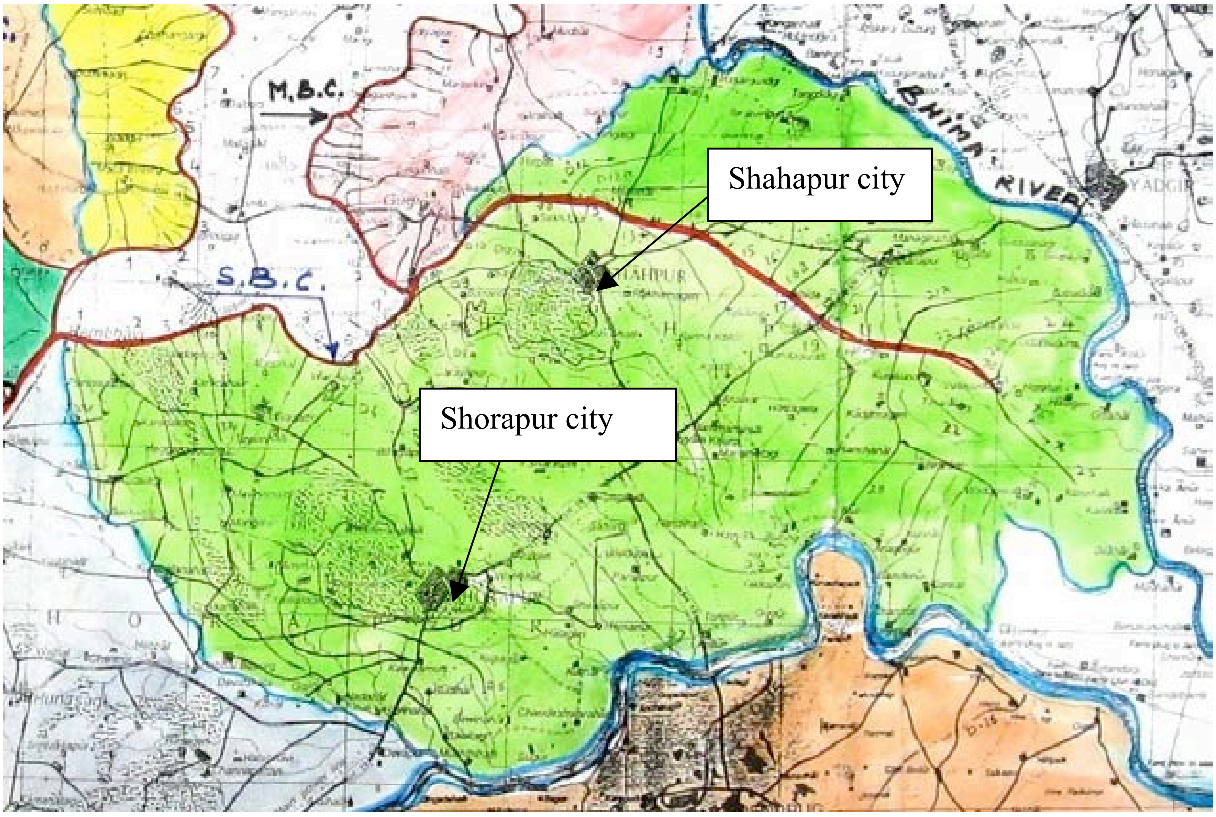

Figure 2. Map of the Shahapur Branch Canal

The Shahapur branch canal is located in the downstream stretches of the left bank canal, between the Krishna and the Bhima rivers as shown in figure 2.

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 informally/unofficially emerge by practice.

SBC irrigation scheme was originally built for 3 services:

- irrigation water supply,
- flood control.
- Power production

In practice at least 7 different water services can be found in SBC. These water services are listed in table 3 based on the classification proposed by the Millennium Ecosystem Assessment (see box 1).

Table 3: Water services met in SBC, classified with the MEA grid.

Provisioning Services	Regulating Services	Supporting services	Cultural Services
• Irrigation • Domestic water • Water for cattle • Industry and business (Tourism) • Hydropower	• Environmental flows (drainage - support to natural ecosystems) • Flood protection	None	None

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

Although the services to irrigation is quite recent in the area, the cropping pattern is already quite diversified as one can see from Figures 3 and 4 . Cotton, bazra, turdal and paddy are the main crops for Kharif (wet season) totalling 80 % of the cropped area. For Rabi (dry) groundnut on 25 % of the area is added to the other 4 maim crops.

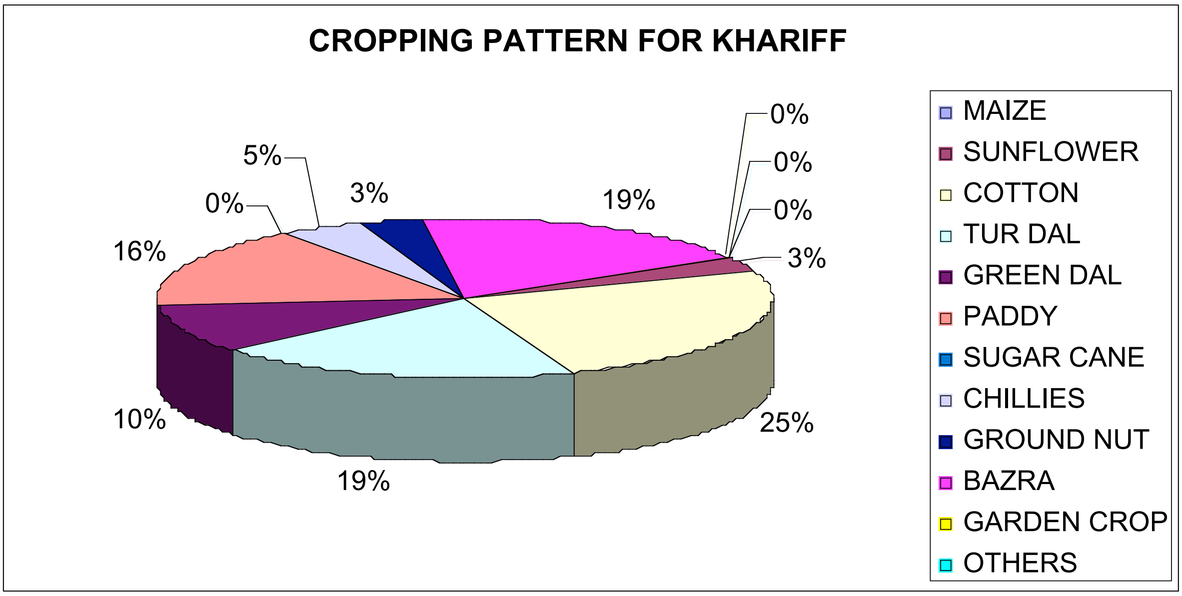

Figure 3 Cropping pattern for kharif 2007-2008

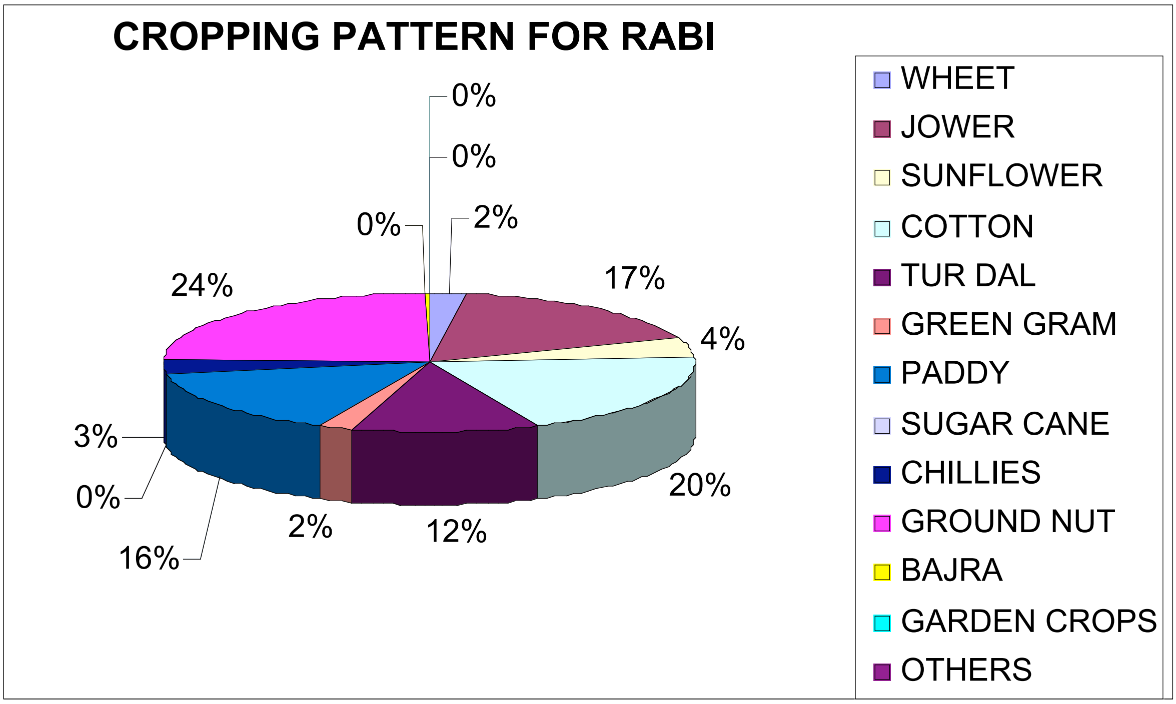

Figure 4. Cropping pattern for Rabi

Obviously the official cropping pattern is not followed by farmers leading to problems of over irrigation in some places and deficits elsewhere. The findings of the MASSCOTE exercise in the whole command area are reported in Box 2. Some statements are strictly related to irrigation services and reflect the issues found: overcropping of rice, rotation not followed, inequity, water logging upstream and deficit downstream, etc..

Plate 2. Cotton and paddy in SBC

Box 2. Common findings reported from the field visit during the MASSCOTE exercise for all systems

Gigantic water infrastructure that should be well managed to serve generations to come, avoid food shortage and generate good incomes for rural population.

Management shift from construction phase to water management has not yet happened.

High distortion Official/Reality at management and users levels

Measurements, assessment and monitoring extremely poor

Multiple Uses of Water is significant in the CA: Hydro – Domestic to towns – domestic to villages /to people – Environment – Fishing.

Involvement of all users and stakeholders should be increased in water management.

Spreading water all over is good for easy access to water services, but it also generates shallow water stagnation in non drained shallow buckets with invasive vegetation.

Drainage flow important (Nala): Water losses!

Water Services should thus include drainage.

In some subsystems probably 50 % rice cultivation is observed.

Water distribution not controlled

Rotation not followed leading to shortage of water at tail.

Lack of gates below disty heads making rotation impossible

Low flow spreading all around low efficiency of transport

Seepage losses due to deteriorated lining of the canal

Too much water flows in upstream distys.

Inequity Tail-enders deficit within Disty

Domestic Water Services

The SBC contributes to domestic water supply for about 75 % of the population of Shahapur taluka, with a per capita rate of 90 litres/day. Similarly the KBJNL Bheemarayangudi camp is also drawing water for the domestic purpose for 6000 population at a per capita rate of 45 lts/day, to cope up with the shortages of present water supply.

To specifically define what do we mean by domestic services in an irrigated command area we borrow from the WHO and UNICEF (Howard and Bartram, 2003) assessment, they state that *"one-sixth of humanity (1.1 billion people) lacked access to any form of improved water supply within 1 kilometre of their home"*. This statement can then be used to define the domestic service and identify and demarcate people and regions those are being served from those who are not.

Further the Joint Monitoring Program [WHO/UNICEF – JMP] specifies what "improved water supply" means as shown in Table 4.

Table 4. Type of improved and unimproved water supply according to the JMP.

Improved Water supply	Unimproved water supply
Piped into dwelling, plot or yard Public tap/standpipe Tube well/borehole Protected dug well Protected spring Rainwater collection	Unprotected dug well Unprotected spring Cart with small tank/drum Tanker truck Surface water (river, dam, lake, pond, stream, canal, irrigation canal) Bottled water

The previous grid must not be taken as a warranty for safe water. JMP cautions that the grid does not allow establishing a relationship between safe water and access to improved water supply. For instance bottled water is in more cases safe and water from house connection can be contaminated due to weakness in the treatment or recontamination along the network.

We thus consider that:

1. In an irrigation command area, basically we are mostly dealing with surface water which has to be considered as raw water (untreated) therefore unimproved and most probably unsafe.

2. Within an irrigation command area the "1-KM-Access definition" can serve as the threshold between populations served for raw domestic water from those remaining unserved.

With this in mind the question of service coverage is then reduced largely to the density of various types of canals in a command area.

Domestic water supply to villages

The service of domestic water to villages by tank supply or groundwater recharge. In the example shown in plate 3, the Shettykara tank/village, one can find both the tank used for washing and the near by well used for cooking and drinking. The surplus water of distributary and laterals of D-6 and D-9, flows in to the natural streams and nalas and contribute to the water for Shettykera tank which is used for fishery and minor irrigation purpose. The water table level at this region has considerably increased and the open wells are serving with sufficient water.

Consistent with the previous guess for individuals we have considered that 70 % of the fraction of people who are not living in cities are dependant on water served by tanks and shallow groundwater recharge/refilled by irrigation water. This guess leads to some 182 000 people use these services.

With this service (tank-groundwater) the canal off period is less a problem. If the storage capacity in surface and in the groundwater system is enough to cope with losses and uses during the closure, then users won't face any restriction in terms of quantity. Water quality in tanks might deteriorate when surface supply is off, this must be monitored.

Domestic water to cities

The water services to cities correspond to a specific delivery at one point of delivery (Reservoir or Pump station). In SBC raw water supply is provided by gravity to the Shahapur city in a buffer reservoir upstream of the city (see plate 4.). According to the water supply company, approximately 30 % of the 45000 city inhabitants are fed by 116 tubewells and 70 % by irrigation water after treatment.

The volume of the Shahapur reservoir corresponds to a consumption of 2.5 months, therefore there is often a gap at the end of the off period of the irrigation canal (3 months). The volume of water supply per capita at the reservoir is estimated to be at 230 liters/day/capita. This of course includes the losses in the treatment and distribution and is far above the actual consumption per capita. In that case it seems improving the efficiency in the water process and distribution would solve the problem of making ends meet.


Plate 3. Supply to Shettikera Tank: access for washing (left) and open well near by

Plate 4. Shahapur City Domestic water Reservoir fed by irrigation pipe.

Surface water stream domestic services

The surface water stream services are provided by canals, rivers and drainages. Water is used for bathing and washing but also for cooking and drinking with obviously high risk of contamination for the later if the water is not properly treated. Quality of surface water is a major concern especially for cooking and drinking. It is always better to use water from a near by well than the surface water itself, as there is a filtering and cleaning process in between.


Plate 5. Handpump along canal (left) or direct access to secondary canal (right)

Table 5. Canal water services analysis.

Type of canal	Presence	Service	Quality	Problem
Main Canal	Permanent during irrigation season	Reliable Adequate	High if the source is good	Safe access often not provided
Secondary Canal	Permanent Rotation are also met	*Upstream*: Reliable Adequate *Downstream:* unreliable and lack of water	Medium	Safe access often provided
Tertiary Canal (Lateral)	Rotation very often	*Upstream*: Reliable Adequate *Downstream:* unreliable and lack of water	More risk of contamination by upstream users	Easy access
Drainage canal	Permanent [Often purposely no repaired leakages on the infrastructure]	*Service tolerated to feed areas away from canals and/or landless people leaving on the banks*	Quality is a big issue if quantity is low	

Extension coverage of services

The application of the JMP 1Km-access criteria shows that on average the entire command area of SBC is served by either the irrigation canals or drainage as illustrated in Figure 5. Therefore potentially all people living in the command area can be benefited by improved water supply from the irrigation canal. Those who really directly benefit are obviously those not connected to a domestic network. But even those connected with the supply are one way or the other supported by the irrigation infrastructure.

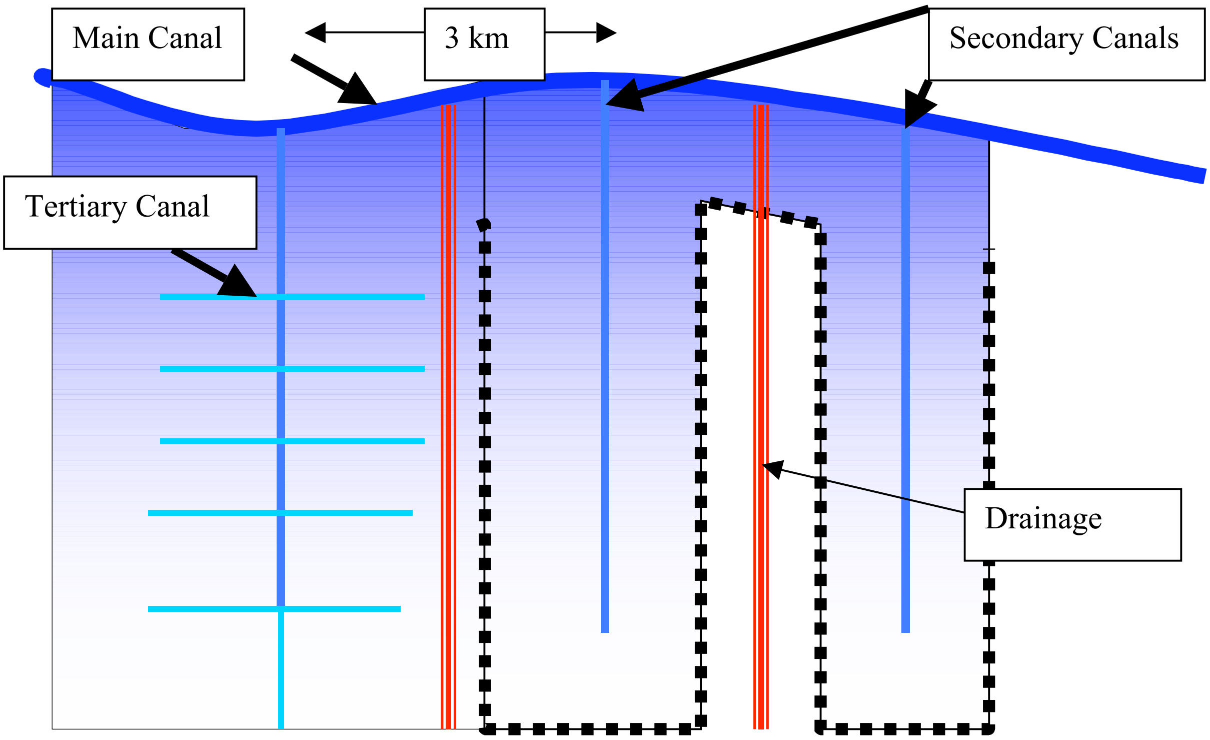

Figure 5. Zoning around the canal infrastructure for Shahapur Canal – Right blue Main and secondary canals – Left red with tertiary canals considered – Drainage network.

The first critical issue is the quality of domestic service provided by the canal system which degrades as we go downward along the infrastructure. By design the rotation is more important on lower canals, and that leaves long period without water in the canal. By practice the quality declines as the result of upstream uses and by lack of operational performance; adequacy and reliability decline downward.

The second critical issue for the surface services is when the canals are closed during the off season for a period of 3 consecutive months. People have then to travel long distances to find water in well fed wells, tanks, rivers and lakes.

Losses or hidden water services for other uses?

There are many places along the SBC canal network where leakages occur, from water gates at escape or in the banks of the canal. In plate 6 example of such water leak is given. Whether these losses are real losses or whether the flow that escapes from the canal is de facto used by people living along the drainage is a major question. This situation is very common in fact in Karnataka, and many managers are not willing to repair leakages knowing that users may suffer downstream and may try to deteriorate the gate or the canal. These leakages are thus purposely tolerated for crop or to satisfy other uses (domestic, cattle, etc..).

Plate 6. Servicing drainage escape ditch: non repaired leakage on an escape gate to served population along the drainage (Y Jonction Naryanpur canal)

Drainage services

In the initial reaches of the SBC canal network, large surplus of water are flowing from the paddy fields and tail ends of the distributary and laterals, because of improper irrigation practices and water management causing serious water logging, salinity problems and growth of the swamps and weeds increase which indirectly causes the growth of mosquitoes and unhealthy conditions (Plate 7).

Plate 7 Drainage services: invasion of vegetation

The critical issue of water stagnation, vegetation proliferation and drainage in SBC

Geomorphology of the Shahapur subsystem is characterized by a waterproof substratum made of granite. Drainage is constrained by natural rock weir downstream of many flat areas (Plate 8). The low drainage capacity of this flat areas leads to water stagnation when water is abundant, and it has been always so during monsoon time.

The recent introduction of irrigation supply has created abundance of water almost throughout the year and there are now many places where this phenomenon has created permanent water stagnation on surface, small ponds. One of the negative impacts of that situation is an invasion of undesirable vegetal species and jungle as illustrated in Plates 7 and 9.

Plate 8 Example of topo sequence of flat land surrounded by granite boulders in SBC.

Drainage should be considered as part of the water management in order to prevent externalities of irrigation as water stagnation.

Plate 9 Downstream a village: water stagnation in a topographic depression with invasion of vegetation

Shallow surface water stagnation is not desirable because it leads to proliferation of aquatic vegetation, also create conditions for mosquito's breeding, therefore the alternatives for managers are:

- Create a tank with a raised water level to prevent vegetation development (many tanks exist in the area)
- Drastically reducing the drainage water by acting on irrigation water supply.
- Channel the drainage flow through or around the depression to avoid wide stagnation.

The critical issue of water management for the whole CA of SBC

Surface water leaving the command area is not measured and is not accounted for, while the field visits made downstream Shahapur BC show that significant flows are leaving the CA (see plate 10). In one case, measurement weir is there but not used and in another case specific measurement devices should be installed.

Plate 10 Downstream of Shahapur BC, weir with possibility of monitoring the flow (left) – bridge which should be equipped with measurement device (right)

Flood protection

The positive effects of the main reservoir on the flood regimes downstream of the dam are incontestable. That concerns all the areas of SBC close to the Krishna River. No precise data was made available during the workshop on the positive effect of the reservoir in decreasing the extension and gravity of floods in the Krishna river valley downstream of the reservoir.

Environmental flows: support to natural ecosystems

The environmental dimension of water management is gaining momentum in the area. One good example is the lake near Shorapur which has been established as a reserve for birds. During the dry season the water supply of the lake is ensured by drainage coming from irrigated areas upstream. The flow reaching and going out of the lake is quite significant. A low head micro-power plant is under construction at the outlet of the lake.

If quantity does not seem to be an issue, a major concern should be the quality of drained water from agriculture areas which is highly dependant on the practices upstream.


Plate 11 Lake (near Shorapur) as a sanctuary for birds.

Water for cattle

Cattle in the area is of great importance for farmers and people. We estimated approximately 3 people and 3 animals (medium to big) per hectare of land. The number of animals and water consumption statistics are reported in table 6. In terms of quantity of water use the animals represent a negligible share of water use, in SBC 1.5 Million *versus* a total of irrigation water of 1200 Million of m3.

Table 6. Accounting for animals and their water consumption in SBC

Animals Water consumption	type of animal	liters/head/day	m3/head/annual	Number of heads	Volume consumed Million m3
Big size	Cattle Buffaloes	20	7.3	145460	1.06
Medium	Goats-Sheeps-pigs	7	2.555	167460	0.423
small	Poultry	0.15	0.05475	118677	0.0065

Plate 12 Cattle accessing water

Small Business

Small businesses associated to canal water are noticed here and there as shown in Plate 13, but no survey allows to specify whether this is an important activity or not. In Shahapur command area no significant industry using water is reported.

Plate 13 Small business (Traditional Patchwork)

Power production

The SBC is serving water for five Hydro electric power generation stations, which are constructed along the main canal and one station is constructed on the Distributory No.9, and total electric power generated is 7.6 MW. The power plants are managed by private companies. The annual production is of 20 Million KWh which at a selling price of 2.9 INRs/KWh represents monetary outcomes of 58 millions INRs.

The power plant shown in plate 14 above has the followings characteristics:
Head = 6.5 meters; Capacity 1.3 MW; Discharge = 782 cusecs = 22.3 m3/s;Turbine type Kaplan

Plate 14 Power generation station on SBC

STEP 1 SPECIFIC Rapid Appraisal Procedure (RAP) for MUS

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 7.

Table 7. Elements to be filled in 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 detail in Step 4: water uses and benefits.

Internal Indicator 1: Number of Services

Although SBC was designed for two additional services (power production 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 SBC this indicator establishes itself to a high 7 services as reported earlier in table 3.

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 MASSCOTE exercise, the Shahapur system has been ranked as 3 for MUS integration. Table 8 below provides the criteria used for ranking MUS integration.

Table 8. 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 services if there were no canal irrigation. Both quantity and quality of water must be considered for the rating of importance.

When plotted against the number of water uses in the system (figure 6) 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).

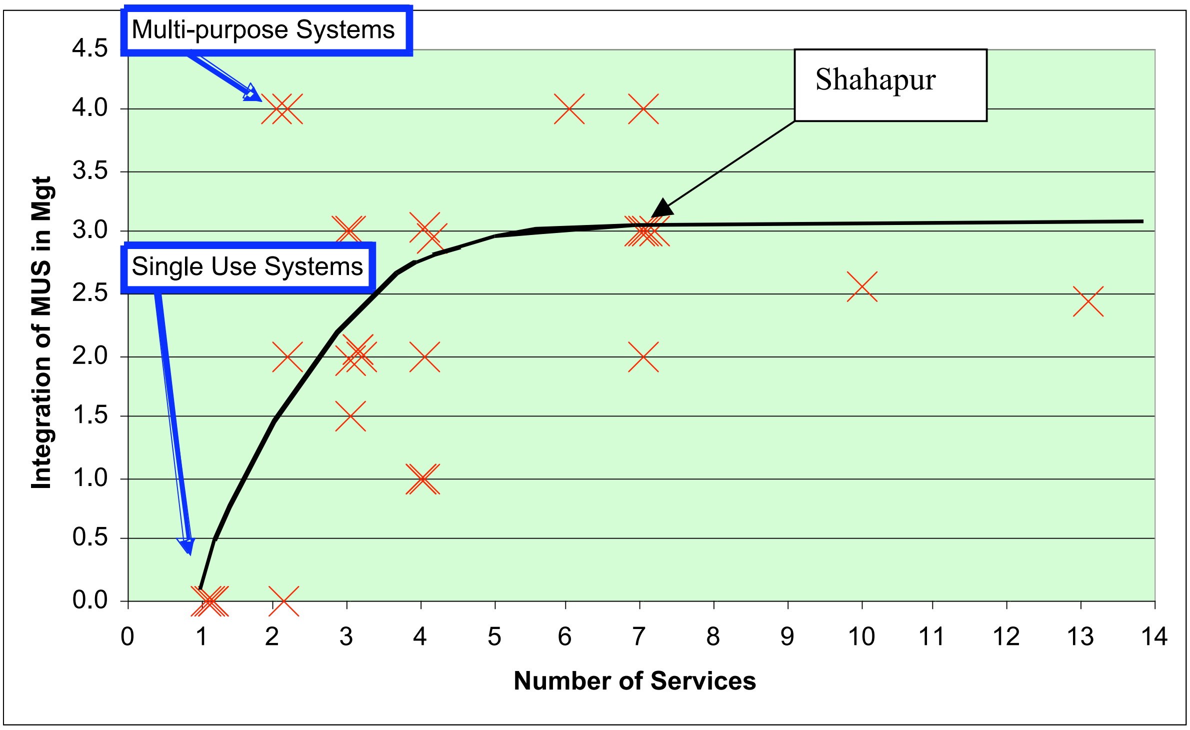

Figure 6. Degree of MUS and integration in management 30 irrigation systems audited by FAO

STEP 2. CAPACITY & SENSITIVITY for MUS

Capacity of the infrastructure

In MASSCOTE approach, capacity and functionality of canal systems are assessed for each physical structure with respect to four main features:

- **functionality**: whether the infrastructure/structure is functional or not;
- **capacity**: if functional, what the actual flow capacity of the structure is with regard to its function (possibly compare with design and/or ideal target);
- **ease of operation**: how easy the structure is to operate;
- **interference**: whether the structure has adverse impact on the behaviour of other structures (perturbations to other hydraulic structures).

Capacity and Sensitivity for Multiple Services

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 MUSF is also a calendar issue throughout the year.

The requirement to maintain the capacity for other uses may then drastically reduce the period of closure of the canal and thus the time allocated for repairs and maintenance. This is for instance practiced in the Indus River basin irrigation systems, in order to not let the areas without water supply for a too long period of time. Considerations on population heath are dominant here but this is often conflicting with the requirement for repairs and maintenance works.

Capacity in assessing physically the water system is sometime critical and an issue of safety. Easy access is quite often provided along secondary and tertiary canals through construction of stairs (Plate 15 right) but along the main canal the situation is different and it can be very dangerous. Women are at risk when washing their clothes just standing along the slope with no safety protection as shown in Plate 15 left.

Plate 15 Left Lack of provision for accessing the SBC main canal; Right access provided along secondary equipped with stairs.

Table 10. Example of capacity and sensitivity for multiples Uses

SERVICES	Characteristics required for the service	CAPACITY	SENSITIVITY
Domestic Water	• Highly reliable controlled flow • High quality of water	reduced during canal closure	High sensitive to deficit and pollution
Water to cattle	• access to canal water • supply to water ponds	reduced during canal closure	
Groundwater recharge	• canal seepage • Field losses • specific recharge facilities	Reduced by canal lining	Low sensitive
Homestead garden	• groundwater pumping igh water table to feed root system	Groundwater recharge and percolation from adjacent fields	Low sensitive
Environment	• Environmental flows	Availability of water	Water scarcity Pollution
Fishery	Presence of water	Minimum water flows or volume in water bodies at season's end.	sensitive to long term quality

Improving the capacity

It is possible to improve the capacity of serving animals by creating ramps to provide a safe access to the canal water as shown in plate 16 for systems in Bhadra Karnataka and in Uttar Pradesh.

Plate 16 Examples of ramp easing water access for animals (Bhadra Karnataka-left; Main Ganga UP -right) .

STEP 3 PERTURBATIONS for MUS

In general terms and having MUSF in mind, 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.

Mapping and managing perturbations

To be able to incorporate perturbation in management and operation of the system, mapping perturbations is essential. It means identifying and characterizing their dimensions as well as the option to cope with:

- origin;
- frequency and timing;
- location;
- sign and amplitude;
- options for coping.

Managing perturbations has two basic objectives:

- ensure passing variable flows without adversely affecting on line services;
- ensure that the perturbation is managed properly, by coping with service perturbation, e.g. compensating for a deficit of water if the perturbation is negative, or by storing the surplus if it is positive.

To achieve these objectives, there are two options:

- Set up an infrastructure in such a way that perturbations are dealt with automatically, e.g. the surplus is diverted automatically towards areas that can store or value the water.
- Detect the perturbations and have a proper set of procedures for the operators to react.

For analysis, the perturbation domain is divided into two components: (i) generation; and (ii) propagation. These can also be termed “active” and “reactive” processes.

The active and reactive processes can be analysed in three constituent parts:

- the causes of perturbations, such as return flows, illicit operation of structures, and drift in the setting of regulators;
- the frequency of occurrence;
- the magnitude of perturbations experienced.

STEP 4.1. WATER ACCOUNTING for MUS

Water accounting, also called water balance, refers to the accounting of the influxes and outfluxes of water in a given space and time. Water accounting is an important part of the MASSCOTE process and the foundations for a modernization project. MUS does not bring any specific demand for water balance but it heavily reinforces the need to measure each and every use of water in the gross command area.

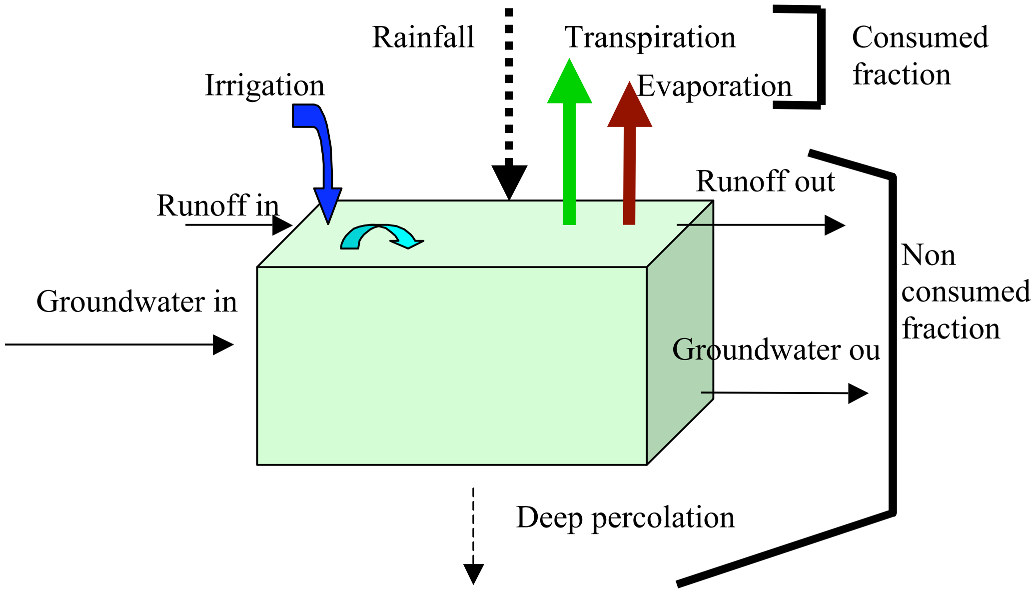

Figure 7 Sketch out of water balance of an irrigation system.

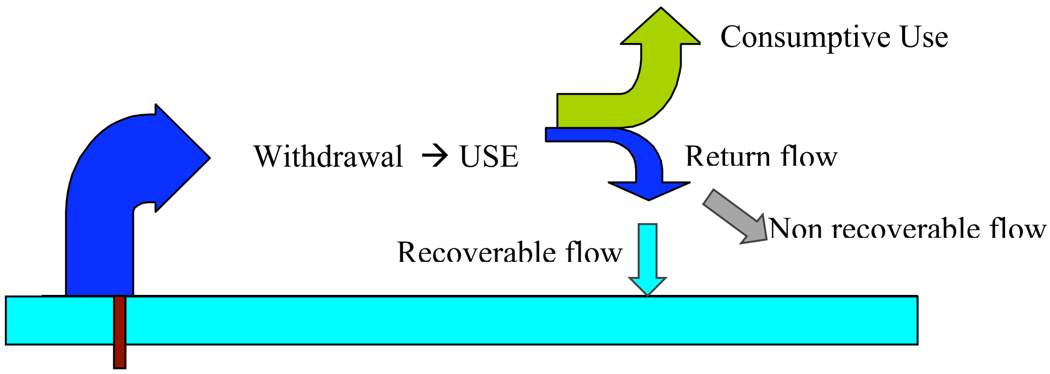

Figure 8. Sketch out of water partitioning: consumptive use and return flow.

Water in & Water out

Water accounting must consider all water (surface water and groundwater streams, conjunctive use, storage and recharge, etc.) that enters and leaves a defined area in a particular span of time.

As "water in" we have to account for precipitation in the CA, the GCA, Runoff from adjacent watershed, groundwater net contribution and of course irrigation water. As "water out" we have to account for Evapotranspiration (ETP) often the main component, the runoff out and the groundwater lateral out.

Water use

Using water might have several meanings which essentially are related to one of the following characteristics:

- Quantity: a water use can consume water
- Quality: a water use can reduce water quality
- Energy: hydropower water use consume the elevation (energy) of water to produce electricity.

Furthermore there are several ways of qualifying water use using the following criteria as illustrated in table 12: water uses can be depletive or non depletive, consumptive and non consumptive, processed or non processed, but all have to be somehow evaluated to develop a comprehensive MUSF approach.

Table 9. Characterisation of water use

Characteristic of the Use	Definition	Example of such use
Consumptive	Water leave the system (hydrological cycle) and return to atmosphere	Irrigated crops Homestead garden Perennial natural vegetation
Non-consumptive	Water is not consumed. Water maybe diverted and used but is returned after use.	Hydro-power Domestic water (recycled) Animals
Depletive	Water is depleted from the natural resources	Diversion schemes Groundwater Pumping
Non depletive	Water is used on its site without any diversion	Recreational use in aquasystems Landscape tourism
Process	Water is needed by the associated producing process.	Crop growth hydro-power
Non process	Water consumed is not part of the process, but rather a side effect	Fisheries and evaporation from water bodies Tourism, recreational value
Beneficial	Positive externalities	Groundwater recharge
Non beneficial	No added value. Negative externalities	Pollution from agriculture areas.

***Nota**: the qualification of the water use as in table 13 is not always clear cut.*

Consumptive use means water leaves the hydrological cycle. We found in this category all uses associated to evapotranspiration process: it is either the result of a direct process consumption such as evapotranspiration for crops or for perennial vegetation in the GCA or an indirect consumption (they are not necessary for the process) such as evaporation from water bodies for fisheries, environment, recreational and tourism.

Non consumptive uses are the ones which return large part if not all of the fraction they have taken.

Note that evapotranspiration is not the only consumptive use, in this category falls also the fraction of water sunk into deep groundwater aquifers or water which becomes unusable after too much degradation. However they area more seldom and this is why here we have restricted this category to ETP.

Depletive Uses: Evapotranspiration

The consumptive use of water is mainly due to evapo-transpiration, water returning back to the atmosphere. The rate of evapotranspiration is highly related to the nature of land use and its water status (well fed or dry).

From Uses to Beneficiaries

Identifying beneficiaries and benefits of water uses are important to appreciate the importance of each use within the GCA. For instance one step is to say that for example 8 % of total water is evaporated from the water bodies within the GCA, the second step must identify who are the beneficiaries sharing the values/benefits associated to this use. A similar reasoning must be made for the natural ecosystems.

Uses and beneficiaries sometimes coincide, e.g. for crop production and farmers, in that case the measure of water outputs is affected to one single use. Coincidence between one use and one beneficiary is not always met, e.g. water bodies evaporate water but this use can be related/associated to many beneficiaries (fisheries, tourism and recreation, environment and wildlife, transport,...). This latter point is addressed below.

Partitioning benefits of water bodies

Some consumptive uses are unambiguously associated to one single use like crop production, or homestead garden, natural vegetation, although they might yield to several beneficial outputs.
Some consumption corresponds to several uses or function of water and it is not straightforward to partition the consumption according to these various associated uses. This is in particular the case of water bodies such reservoirs, lakes, tanks etc... They may serve several purposes: storage of water for the dry season, fisheries, recreational activities, tourism, wild life, flood protection, etc... There are no simple rules to partition the water evapotranspired from a reservoir. Criteria that can be used to weigh the consumption are:

- numbers of beneficiaries, households, jobs
- monetary value generated per use
- environmental values.

Impact of water quality

The quality of water returned in to the system after some use can be deteriorated (pollutant, thermal change, ...) and that has to be considered when water accounting is processed as a whole.

Seizing the various water uses

As said earlier the share of water consumption is the first indicator to look at when addressing MUSF. Figure 9 displays the results of the water use share according to the identified uses of water. The amount of water uses in SBC is estimated to reach 1200 MCM out of that field consumption (crops+fallow period) accounts for 1010 MCM (84 %), perennial natural vegetation for 114 MCM (9,5 %), environmental flows for 57 MCM (5%). Minor use quantity wise are fisheries 11 MCM (1 %), domestic water 6 MCM (0.5%) and animals 1.5 MCM (0.12 %).

In terms of share of the total estimated benefits, crops are bringing some 69%, animals are contributing to 23 % and domestic water to 6%. Electricity produced is only 1 % of the value. Benefits from perennial vegetation have been estimated also at 1 % of the total.

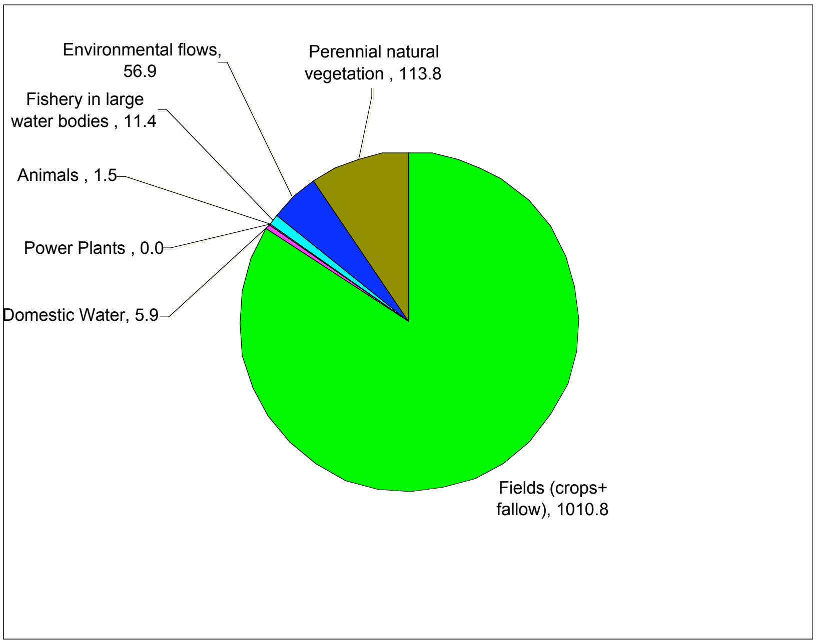

Figure 9. Use of Water in Shahapur system (in MCM).

STEP 4.2. Accounting the benefits of water uses

This step is added specifically to address MUSF system. The values associated to the water uses must be characterized in such a way it can then be used for comparison among uses, for decision making about water allocation as well as for estimating the possible contribution for cost coverage.

- Value per Uses and per benefits:
    - gross product supported from this water service
    - employees
    - households
    - values: monetary and non monetary (social, culture, etc..)
    - Health
    - environmental values
- Theory of Valuation
- Value with respect to all water
- Value with respect to irrigation water (with & without irrigation analysis)

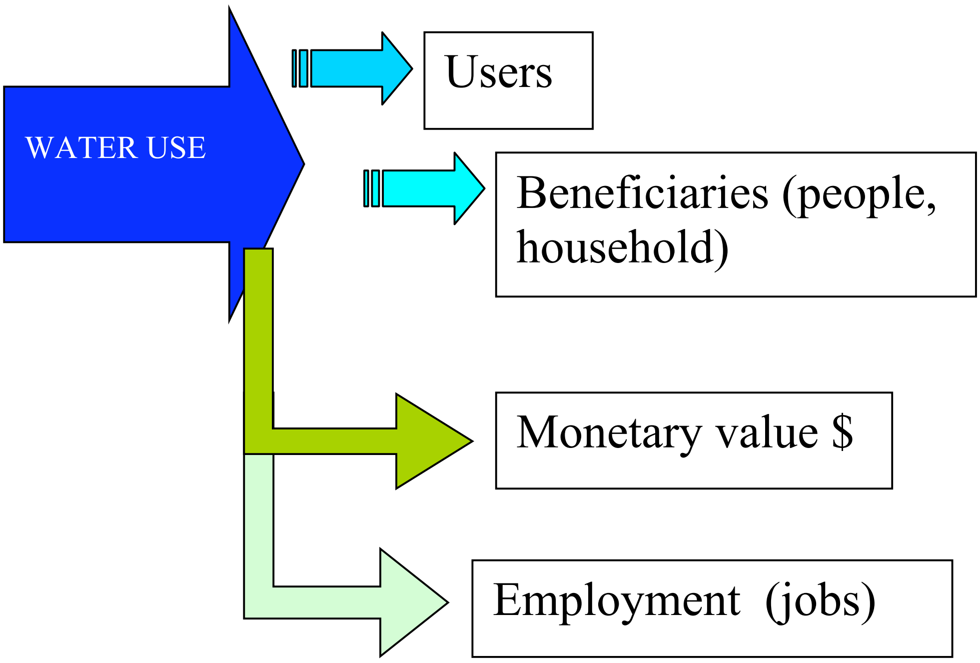

Figure 10. Accounting water use, beneficiaries and values

Table 10. Water Uses and Benefit estimator

Use/function	Benefits estimator
Delivery to farms	Crop yields $/ha irrigated - $/m3
Domestic water	Cost paid by service users Estimated cost of an alternative solution Number of capita served
Drinking water for cattle	Value of annual animal products Number of households
Homestead garden	Value generated by the garden
Support/recharge to natural surface streams (surface and groundwater) & environment	
Industry and Hydropower	Economical value generated, employment
Tourism, fishing, recreation, wild animals & natural parks	Economical value generated, employment
Control of vector-born diseases in waterbodies	
Flood control	Population and assets protected
Control of drainage return flow	
Transport	Quantum transported Economical value, employment

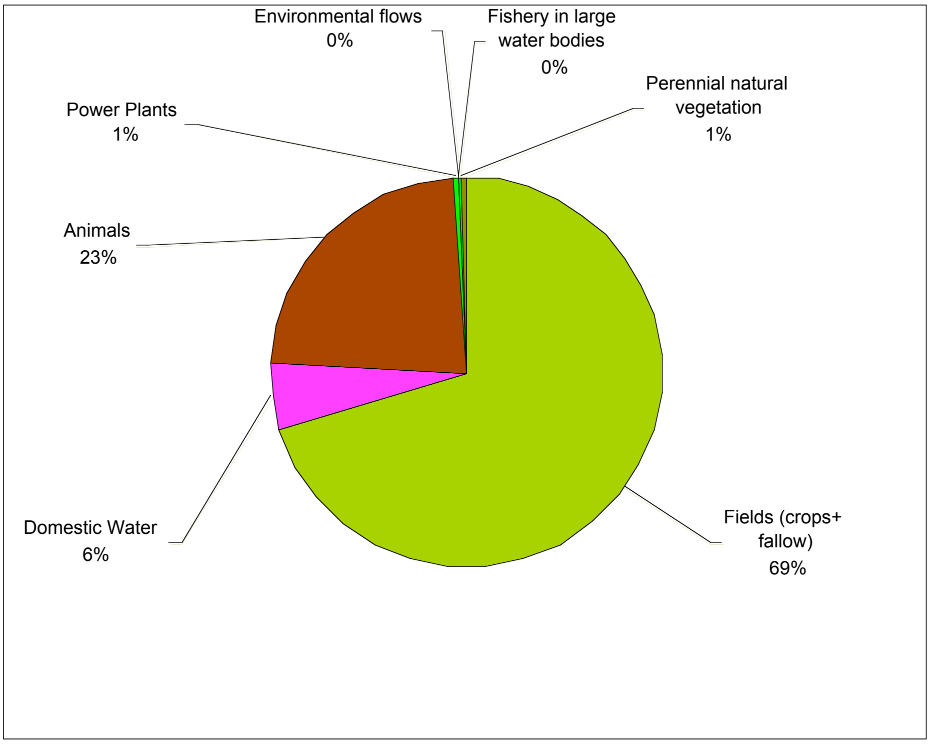

Figure 11 Share of Monetary Value per use in Shahapur system .

Following steps 5 to 10 and perspectives

The MASSMUS following steps are meant to address the cost of operation, the users and the services, the management units, the demand for operation, the improvements and integration in order to generate a consistent plan for modernization.

Due to lack of time it was not possible to carry out these steps for the Shahapur Branch canal during the initial workshop.

Shahapur Branch Canal System is a MUS system with about 75 % of the benefit generated by irrigation, and the bulk of the remaining value by animals. In terms of estimated benefits the other uses seem to be low. In Figure 12, the share of benefits of SBC is plotted and compared with other MUS systems. SBC is the system having the highest share for crop (70%).

A major conclusion of the workshop is that no doubt the SBC is a Multiple Use System.

First recommendation of the workshop for the managers is to complete the MASSMUS.

Second recommendation is to further investigate some of the uses and their benefits. In particular for domestic water to towns, villages, and individuals because the low conservative calculated value does not probably reflect properly the importance of this service in the area. Further investigations should be carried out to come up with methodologies for estimating the benefits of raw water services to the communities.

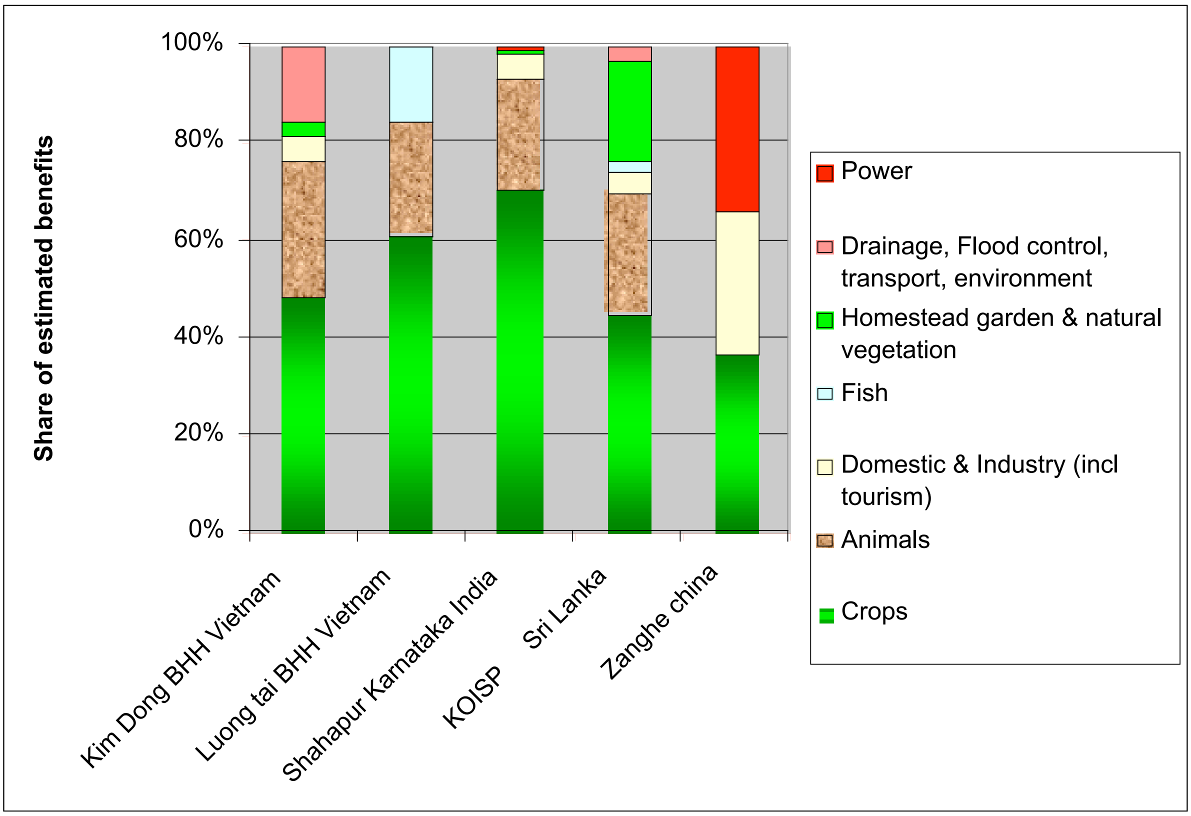

Figure 12. Share of benefits for some studied MUS systems.

DR Dec. 09