Mapping Systems and Services for Multiple Uses in Bac Hung Hai Irrigation and Drainage Scheme, Vietnam

MASSMUS APPLICATION

CURRENCY EQUIVALENTS

Currency Unit = Vietnamese Dong (VND)
US$1.0 = VND 17,788

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

APC	Agriculture Production Company
BHH	Bac Hung Hai
CA	Command Area
CCA	Culturable Command Area
CR	Cross regulator
DO	Direct outlet
DPC	District People's Committee
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)
M&E	Monitoring and Evaluation
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
NCA	Net Command Area (irrigable)
NRLW	Water Service of the Land and Water Development Division of FAO
O&M	Operations and Maintenance
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 management of irrigation system: MASSCOTE (Mapping Systems and Services for Canal Operation Techniques). The need to develop specific approach to multiple uses of water in an irrigation system has materialized 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 exception.

The MASSMUS module is developed in the same way as MASSCOTE, with a stepwise progressive process starting with a Rapid Appraisal Procedure (RAP), and then proceeds 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 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. Bac Hung Hai (BHH) irrigation and drainage scheme in Vietnam was selected for MASSMUS testing due to: 1) its multiple functions, roles, and uses; and 2) recent application of MASSCOTE in BHH.

In June 2009, an expert consultation to test the MASSMUS module in BHH was organised in collaboration with the Centre for Training and International Cooperation (CIC), Vietnamese Academy of Water Resources (VAWR), Ministry of Agriculture and Rural Development, Vietnam. FAO's project "Evaluation Study of Paddy Irrigation under Monsoon regime" (ESPIM) funded by the Government of Japan arranged for the testing of the MASSMUS module and the expert consultation.

This report[1] presents the results of the expert consultation and the testing of the MASSMUS module of MASSCOTE methodology in Bac Hung Hai irrigation scheme in Vietnam. The MASSMUS module was applied in two administrative districts in the BHH: Luong Tai district, and Kim Dong district. These districts were selected for various reasons including extent of multiple uses; easier access to information (particularly in light of the limited time available to carry out the MASSMUS exercise); and the presence of trained irrigation managers in MASSCOTE approach. Owing to the time constraints, all the ten steps of MASSMUS were not applied in these districts, only the first six steps were completed and the last four which look at vision and modernization were not tackled

[1] The report has been written by Robina Wahaj FAO consultant who led the MASSMUS exercise in Vietnam and Daniel Renault Senior Officer FAO NRLW HQ.

MASSCOTE Methodology and MASSMUS module

The generic methodology used in this 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 application of all these steps 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 the various steps of MASSCOTE again 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 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.

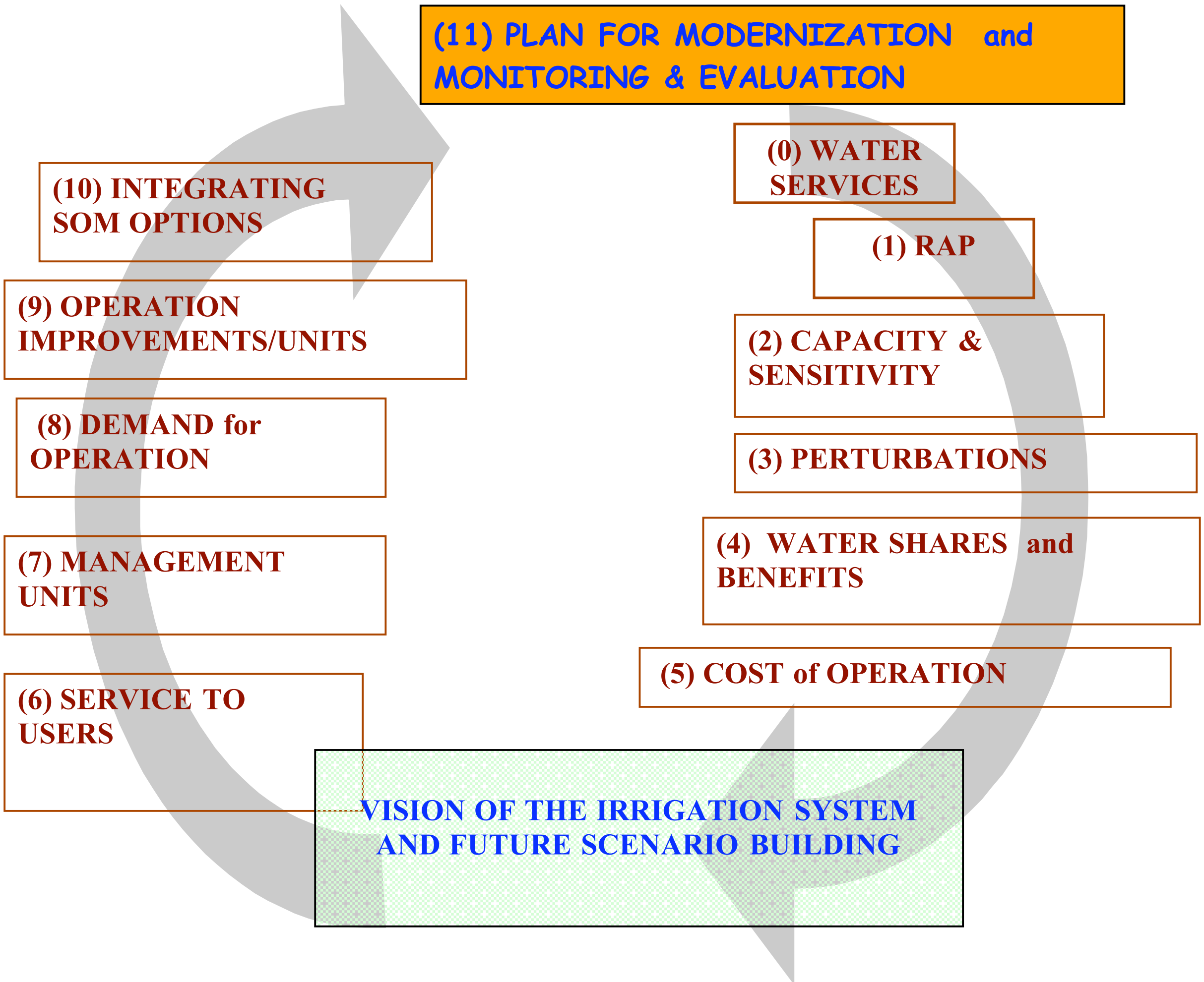

Plate 1. Stepwise MASSMUS process

Brief introduction to the Bac Hung Hai Irrigation and Drainage system

Bac Hung Hai (BHH) irrigation and drainage scheme lies in the northern Vietnam (South –East of Hanoi). It has a gross command area of 214,932 ha, out of which 146,479 is equipped with irrigation facilities. The scheme was built 50 years ago, in different phases, and is in acute need of improvements. The command area of BHH scheme is bounded by 4 rivers: Red River (West), Duong River (North), Thai Binh River (East) and Luoc River (South) (see figure 1). Red river is the main water source, designed to provide water to 90% of the command area in the scheme. Rest of the command area is supposed to be irrigated with the water pumped from 3 other rivers. Due to lowering of water levels in Red River Xuan Quan intake presently irrigates only 55-60% of the design area (111,000 ha) in the peak demand period (January and February), therefore Cau Xe and An Tho outlets/sluice-gates at the tail-end of the system are used to withdraw water for irrigation from Thai Bin river during low tide.

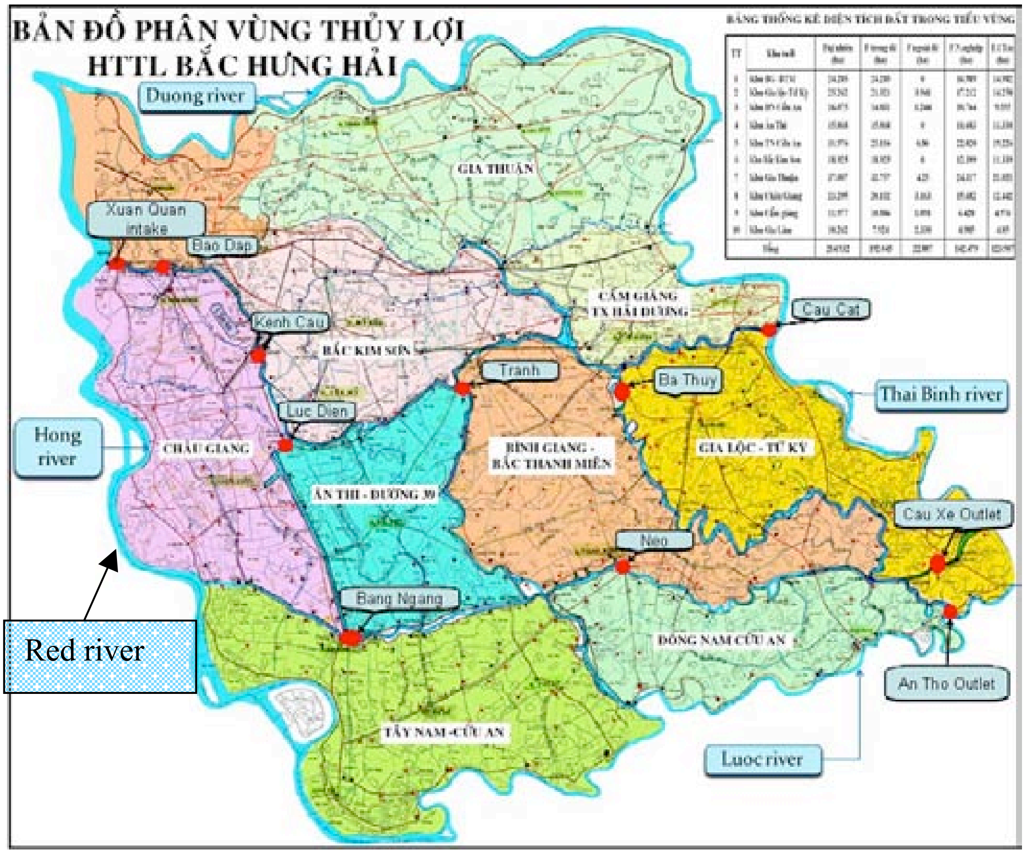

Figure 1: Map of Bac Hung Hai irrigation and drainage scheme

There are 10 sub-command areas or management units in BHH: Gia Lam, Gia Thuan Chau Giang, Bac Kim Son, Cam Giang-Hai Duong City, An Thi, Binh Giang-Bac Thanh Mein, Tu Loc (Gia Loc-Tu Ky), Tay Nam Cuu An, Dong Nam Cuu An. Figure 1 and table 2 provides basic information on the management units.

Table 2: General information of the 10 sub-command areas

Sub-area	Total area (ha)	Agricul-ture area (ha)	Cultivated area (ha)	Population
Gia Lam	10,262	4,985	4,850	384,834
Gia Thuan	37,007	24,317	21,021	409,340
Chau Giang	23,295	15,682	12,442	327,857
Bac Kim Son	18,925	12,399	11,339	229,020
Cam Giang - Hai Duong City	11,977	6,428	4,976	206,996
An Thi	15,868	11,683	11,338	163,666
Binh Giang - Bac thanh Mein	24,285	16,989	14,982	247,679
Gia Loc - Tu Ky	25,262	17,212	14,258	293,138
Tay nam - Cuu An	31,976	22,020	19,226	373,233
Dong Nam Cuu An	16,075	10,764	9,555	176,823
Total	**214,932**	**142,479**	**123,987**	**2,812,586**

Water supply network consist of Xuan Quan intake (plate 2) that diverts water from red river, open canals (and rivers) and about 500 pumping/lift stations (PS) (including 4 big PS for irrigation). Primary canals are rivers, which are not only used for irrigation but also for drainage. Some secondary and tertiary canals are also used for both irrigation and drainage. Most of the cross regulators, particularly at the main and the second canal levels, have motorised vertical sluice gates (plate 3). However, Ba Thuay cross regulator in the Northern main canal/river has radial gates which are manually operated.

Although not included in the design, BHH system also provides water service to industries (water supply for production and drainage), to villages/towns (bulk/raw water supply to the companies for domestic use, and sewage/drainage services), and for navigation. In some areas BHH provides about 8 to 10 different services including water supply to different sector, and sewage disposal from houses, factories and small businesses. Agricultural areas are shrinking while urban areas and industries are on the rise. In the last decade, significant numbers of industrial zones were established.

Plate 2: Xuan Quan intake

Plate 3: Kenh Cau cross regulator

The total population of the area is about 2.8 million people out of which about 2.2 million are working in agriculture. Farmers are increasingly growing high value crops, such as vegetables, fruit trees, and flowers; however paddy rice remains the major crop grown on 80% of the cropped area.

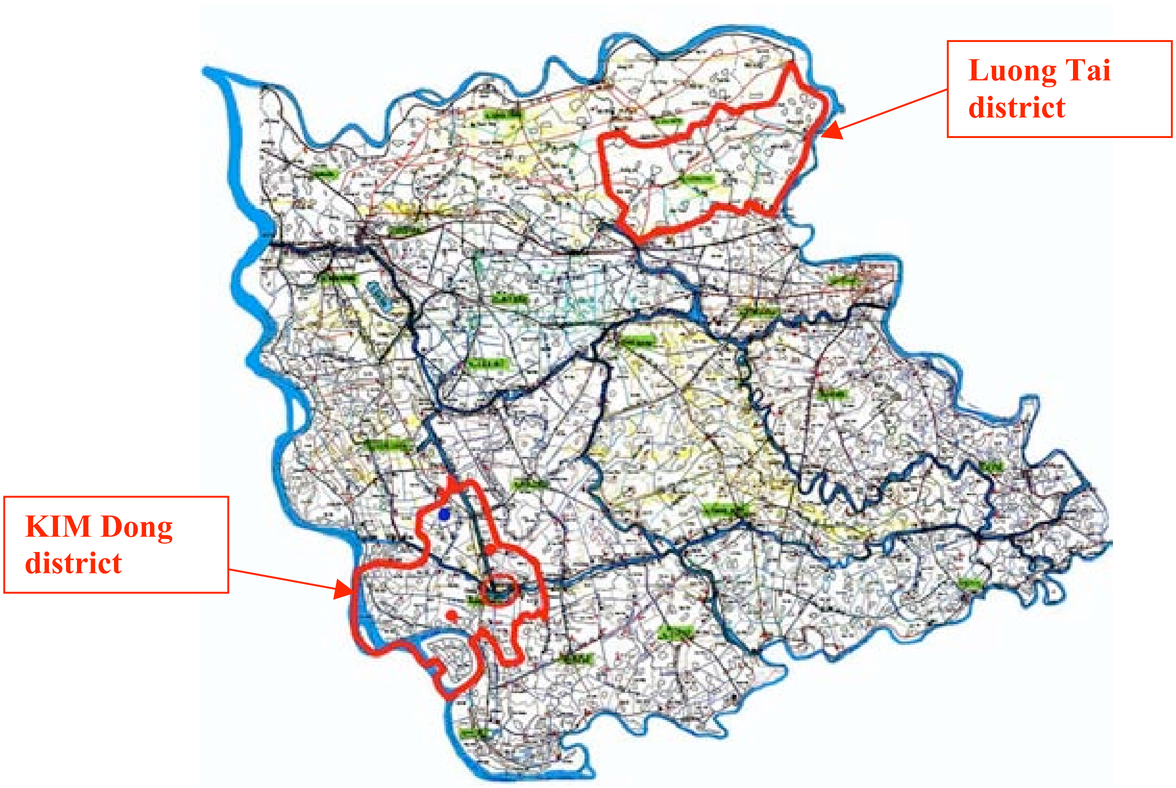

Figure 2: Map of Bac Hung Hai irrigation and drainage scheme

The Government of Vietnam has recently (2008) abolished irrigation and drainage service fee for farmers, which according to the managers of BHH may lead to increase in operation and maintenance budget provided by the provincial Governments and ministry of agriculture and rural development.

The two administrative districts where MASSMUS module was implemented are Luong Tai district and Kim Dong district. The boundaries of these districts are shown in figure 2. The size of the two districts is very similar. The gross command area and area equipped for irrigation in Luong Tai district is 10,567 ha and 5,575 ha respectively. Kim Dong district has gross command area of 11,500 ha, out of which 5,500 is equipped with irrigation facilities. While most of the irrigation water supply to the secondary/tertiary canal network in Kim Dong district is through pumping because of the high elevation of cropped area, gravity canals are mostly used in Luong Tai district for irrigation supply. Multiple uses are practiced in both the districts.

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.

Bac Hung Hai irrigation scheme was originally built for 3 services:

- irrigation water supply,
- drainage &
- flood control.

In practice more than 10 different water services can be found in some parts of BHH. These water services are listed in table 3 based on the classification proposed by the Millennium Ecosystem Assessment (see box 1). The services are the same for both the districts except for transportation which only occurs in Kim Dong district. However, the magnitude of these services is different in both the districts.

Table 3: Water services met in BHH according to the MEA grid.

Provisioning Services	Regulating Services	Supporting services	Cultural Services
• Domestic water • Irrigation • Water for cattle • Fishery • Homestead garden • Industry and business	• Environmental flows (including groundwater recharge) • Flood protection • Sewage/drainage water	• Transportation • Habitat improvements (raw materials for construction, shade, cooling effect, material for flood protection) • Captured fisheries	• Social functions linked to the infrastructure and management

NOTE: All the services listed in table 3 could not be considered in the application of various MASSMUS steps due to several reasons including non-availability of information and/or non-consumptive use of water by a service (for example in the application of Step 4: share of water uses and the benefits). Moreover, some of the services were split into different components, for example domestic water supply was split into water supply to small towns and water supply to villages or individuals.

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

<u>Provisioning Services</u>, the product obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.
<u>Regulating Services</u>, the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.
<u>Supporting Services</u>, 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.
<u>Cultural Services</u>, 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.

Domestic water supply

Water supply companies take water from BHH scheme, without any official agreement and sell this water to households and factories (plate 4). Where this facility is not available, individual households have installed filters and pipes in the canal and divert water to their households (plate 5).

Plate 4: Water supply scheme to a town in Kim Dong district: left - water tank; right - tap in a house

Factories and small businesses and sewage disposal

There are about 20 small to medium factories in Kim Dong districts that manufacture a range of products including car accessories; locks; garments; textile; and food processing. Some of these factories, such as those into food processing, receive water supply from water supply companies. Others use BHH water for personal use of the staff. All of these factories discharge water into BHH. Moreover, these factories also dispose off used groundwater and rainwater into BHH canal network. Water quality is a big issue as this water is not treated.

In Kim Dong district, there is a big fish nursery (about 17 ha) (plate 6), where animal feed is also processed. The fish nursery takes water from BHH twice a year, for two days each time, and for the year rain water and recycled water is used. Water is eventually drained into BHH. Quality is an issue.

There are not many factories and businesses in Luong Tai district. The ones exist include a factory for food processing - which uses BHH water for production, and a handicraft village

– that only discharges waste water into BHH (plate 7). Water quality of un-treated water is a big issue.

Plate 5: People with no access to tap water install filters (in the canal) and take water directly from the canal

Plate 6: Fish nursery in Kim Dong district

Plate 7: Bad quality water released into the canal system: left – discoloured water hyacinth because of chemicals in the drained water; right – this water is then conveyed to the canal through a drain.

Fisheries

Both cultured and captured fish is practiced in BHH. Water for cultured fish is provided to fish farmers. It is not possible to estimate the extent of the captured fish from streams, rivers, and canals.

Cultured fish is practiced more in Luong Tai district (1089 ha and 2178 household) than in Kim Dong district (30 ha and 68 household).

Animals

Kim Dong district has significant number of big – cows, buffaloes (10600), medium – pigs (40660) and small - duck and chicken (951875) animals (plate 8). These animals survive on water from BHH scheme.

Although total number of animals in Luong Tai district is less: big – cows, buffaloes (7271), medium – pigs (31412) and small - duck and chicken (424200) animals; there is a huge pig farm that gets water from BHH (plate 9).

Plate 8: Ducks in a canal in Kim Dong district

Plate 9: A pig farm in Luong Tai district

Homestead gardens
Number of households concerned with homestead gardens in Luong Tai district and Kim Dong district are 17,000 and 8,000 respectively. The main products are vegetables and fruit trees.

Perennial vegetation
Perennial vegetation covers 0.4% and 2% of the gross command area of Luong Taoi and Kim Dong districts respectively.

Environment
BHH managers maintain some water in the canals during the low demand period for irrigation to dilute sewage water from factories in order to improve the water quality.

Flood Control
Flood control was one of the original functions of BHH. According to some estimates, BHH management in Kim Dong district spends about 200 billion Vietnamese Dong (US$ 12,500) per year to pump rain water out of the system.

Transportation
Transportation in water canals is practiced in Kim Dong district. Main products transported are: sand, and other construction material. An estimated 60,000 tonnes of goods are transported every year in the BHH canals running through Kim Dong district. The main management of BHH instead of management at the district or the sub-system level, collects the fee for transportation.

Step 1: The Rapid Appraisal Procedure

A classical RAP considering the entire BHH irrigation and drainage system was initially conducted as part of the MASSCOTE exercise in May 2009. A specific Rapid Appraisal Procedure (RAP) developed for MUS was carried out in the two selected districts of BHH in June 2009.

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 that 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 worksheet 1. The main elements to be filled in for each use or service are mentioned in table 4.

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 Indicators:

Three internal indicators are considered in RAP-MUS. These include:

1. **Number of water services**: This indicator simply establishes the number of water services provided, intentionally or unintentionally, by an irrigation scheme.
2. **Degree of MUS integration**: This indicator establishes the level of MUS integration into the management of an irrigation scheme and the way managers see multiple uses within the command area. Table 5 provides the grid used of ranking for MUS integration;
3. **Importance of each water service**: This indicator establishes the importance of each water service provided by an irrigation scheme.

Table 4. Elements to be filled in for each specific Use 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

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.

RAP-MUS in Luong Tai and Kim Dong District of BHH irrigation and drainage system

The specific MUS sheet in RAP Excel workbook was completed based on one and a half days field visits to the two selected districts.

Internal Indicator 1: Number of water services

Although BHH was designed for two additional services (flood protection and drainage) than providing water for crop production, it is actually providing services to many more uses. In some districts BHH is providing as many as 13 different water services.

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

The degree of integration of MUS, which refers to the actual practices of managers in incorporating multiple use concerns in the operation and management of the system, is reasonably well in BHH. The RAP internal indicator for BHH is ranked at 2.5 on a scale from 0 to 4 (0 is lowest; 4 is highest). When plotted against the number of water uses in the system (figure 3) and compared with other irrigation systems evaluated by FAO, BHH falls in the better integrated systems (belongs to the upper half of the systems).

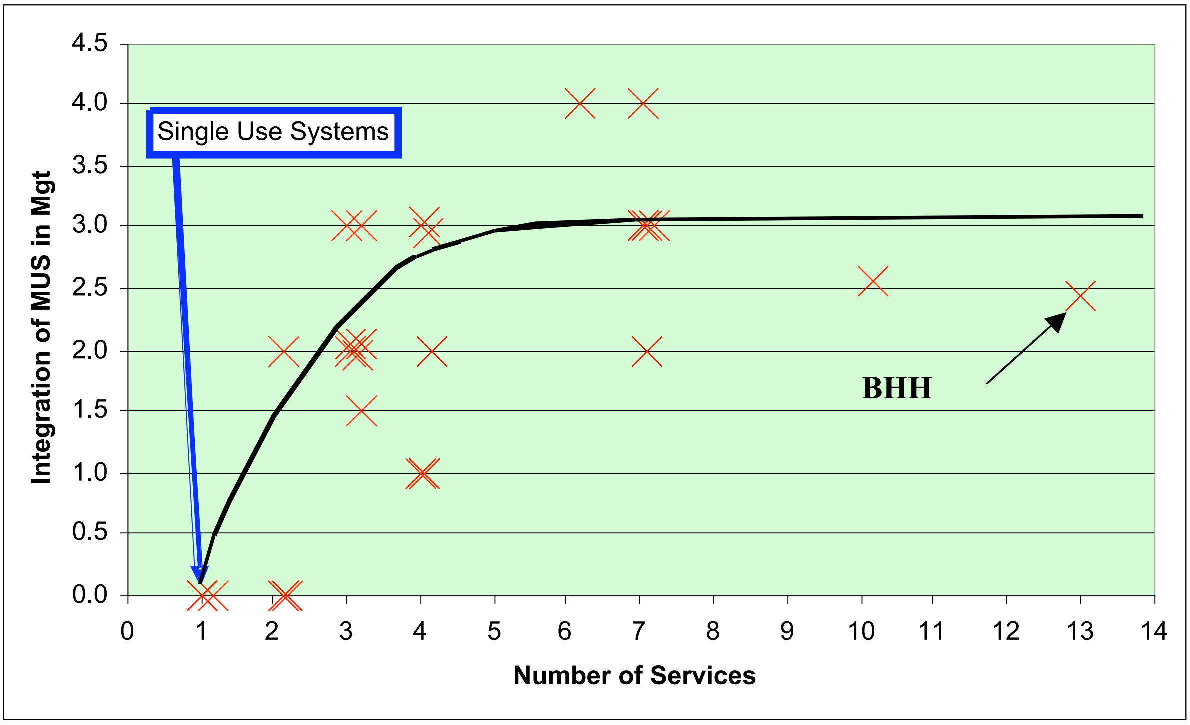

Figure 3: Number of water services and their integration in management in 30 irrigation systems audited by FAO

Internal MUS indicator 3: Importance of each Use/service

The absolute and relative importance of each reported service is appreciated during the RAP exercise through a 0-4 ranking and the results are provided in table 6. Although all the services are important the most important services in Luong Tai districts are crop cultivation, domestic water supply, and fisheries. In Kim Dong districts all the services provided by the BHH system are important.

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

Table 6: Importance of water services provided in Luong Hai and Kim Dong districts in BHH irrigation and drainage system.

Water Use	Importance of water use (0 = not important; 4 = extremely important	
	Luong Tai district	Kim Dong district
Water supply to crops	4.0	4.0
Cultured fishery in ponds	3.0	3.0
Captured fishery in canals	4.0	4.0
Animals	1.5	3.0
Domestic water supply to small towns	3.0	4.0
Domestic water supply to villages and individuals	2.0	2.5
Small industry and businesses	2.0	3.0
Homestead gardens	2.0	2.0
Perennial vegetation	2.0	2.0
Factories, small businesses and sewage disposal	-	3.0
Environmental flows	-	3.0
Transportation	-	4.0
Flood protection	-	4.0

Main findings of RAP-MUS

The main findings of RAP-MUS are the following:

- Multiple uses are practiced in both the districts of BHH irrigation and drainage system. However the extent of multiple uses is different in the two districts. For instance Luong Tai district is more dependant on domestic water supply from BHH irrigation and drainage system, transport in waterways only takes place in Kim Dong district, and water use for industries is more common in Kim Dong district, etc.;
- The main crop cultivated in both the districts is rice, though many farmers are also growing fruit trees/orchards and vegetables;
- Vegetables are grown in the field as well as in the homestead gardens;
- BHH irrigation and drainage system unofficially provides bulk raw water for domestic use through water companies; however in Luong Tai district individuals or households also take water directly from the canals;
- Although water supplied by the water companies for domestic use is treated for water quality, people prefer to use this water for washing; bathing etc, but not for drinking. .
- They use, either rain/storm water or groundwater for drinking;
- Some small businesses, for instance for food processing and fish nurseries use water from BHH for processing/production. Others, such as factory producing car accessories, garment factories use BHH water for staff services - washing and bathing etc; but not for drinking;
- Cattle (Buffaloes; cows, pigs) and small animals are in significant number in both the districts;
- Cultured fishery in ponds is also one of the major water users in Luong Tai district;
- Water quality is more of a concern for many uses, for example for fisheries, than the water quantity;
- Water quality of the return flows is reduced significantly after uses, such as fish farming, animal use, domestic use.
- Water quality of the drainage water from the factories is particularly bad as it is not treated.

- Managers are not really aware of the full extent of multiple services they are providing to different water users;
- Some of the questions and information required to fill in the MUS RAP sheet is difficult to understand and acquire, for example the assessment of water use by homestead gardens, water used by the individuals for domestic use, and water used by the animals.

Step 2: System Capacity and Sensitivity.

For MUS the capacity at stakes is the one dealing with all types of services. Capacity must be seen as a physical capacity as well as time capacity. For instance irrigation canal systems are regularly (annually) shut 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.

The capacity and sensitivity in the two selected districts of the BHH are presented in table 7. There are no major problems of physical capacity of the irrigation network to provide services to other uses of water. Only a few problems of water scarcity are experienced, such as in case of fisheries. Sensitivity to water quality, however, is a critical issue for majority of the water uses in BHH. Water supply to domestic water use, for cattle; and for fisheries is particularly affected by the quality of water that is altered through the multiple uses upstream.

Table 7: Capacity and sensitivity issues in Luong Tai and Kim Dong districts of BHH

SERVICES	Characteristics required for the service	CAPACITY	SENSITIVITY/ Vulnerability
Domestic Water	• Highly reliable controlled flow • High quality of water	• reduced a bit during canal closure – low water level	• 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
Groundwater recharge	• canal seepage • Field losses	• No problem	• Low sensitive to irrigation interruption
Homestead garden	• Canal water availability • groundwater pumping • high water table to feed root system	• No problem for canal water availability; • 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

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 impact of the service delivered, whereas for groundwater recharge, only long duration of shortage can yield to a noticeable change in the aquifer.

Table 8 presents the perturbation analysis: causes, magnitudes, frequency and options for coping with in the two selected districts of BHH. Because of the time constraints this analysis could not be done for individual water uses. Main problems of perturbation in terms of quantity are experienced in January and February when water requirement for irrigation is at its peak; and in July and August, which is the rainy season. Perturbations in quality of water are high both in terms of magnitude and frequency of occurrence. Although perturbations in water quality are experienced throughout the year, they peak in the dry season (from December to May) and in the rainy season (July, August). Monitoring for water quality is a must to establish the level of pollution in the water, which should then lead to enforcements of national water quality standards on the users (in particular on small businesses).

Table 8: Perturbation analysis in Luong Tai and Kim Dong districts of BHH

Items	Quantity	Quality
Causes	- fluctuation (Low water level) in outside rivers - Degradation – operation of structures (sudden stoppage of pumps; cross regulator operation) – mainly for domestic water supply and fisheries - Inaccuracies in water distribution	- Wastewater from agriculture, industry, domestic, cattle farms; poultry farms; fish farms
Magnitudes	medium	- Seems high but have no data to evaluate water quality. - handicrafts industry – high pollution
Locations	- At the beginning of canals - At tail of the system	- In downstream of discharge points (throughout the system)
Frequency	- Jan and Feb in dry season - July and August in rainy season	- Often; throughout the year but particularly bad in the dry season (Dec-May, water in the main river is low and no rain)
Options for copping with	- Conveyance capacity of the canals should be improved to transport water downstream - Storage water on canals to use in emergency cases (already happening) - Improved water distribution plans and infrastructure operation	- National standards of water quality in wastewater discharge should be implemented - Enforce penalties to businesses violating the standards of water quality - Setting up Monitoring system of water quality - Factories and businesses should have waste water treatment plant

Step 4: Share of water uses and Benefits

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.

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 it serves as the foundation 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 to size the water share of each use. Table 9 provides the characteristics of water use in Luong Tai and Kim Dong districts of BHH.

Table 9: Characteristics 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.	Domestic water (recycled) Animals; Environmental flow; Industries; Fisheries; Transportation
Depletive	Water is depleted from the natural resources	Irrigation; Domestic Businesses; Fisheries in ponds Animal farms
Non depletive	Water is used on its site without any diversion	Ducks in the canals; Fishery in the Stream, natural water bodies; canals Recreation Transportation
Process	Water is needed by the associated producing process	Crop growth Food processing Domestic Animals Environmental flows????
Non process	Water consumed is not part of the process, but rather a side effect	Captured Fisheries and evaporation from water bodies recreational value
Beneficial	Positive externalities	Groundwater recharge
Non beneficial	No added value. Negative externalities	Pollution from agriculture areas; pollution from industries; animal farms; small businesses

Water Productivity in BHH

Productivity of different uses of water was assessed for both the selected districts using estimates of water provided to each use and the gross value of money generated from them. Water supply to different uses were estimated based on the information from the managers of each district as it is not measured for any use except for the domestic water supply. Water supply companies, which provide water to the individual households and factories measure water and charge it according to the volume delivered. It was difficult to estimate the gross value of production of some uses or services provided. In these cases, for example drainage service for sewage water, actual fee collected by the district irrigation authorities was used as value generated. Similarly revenue collected by water companies for domestic water supply was used as gross value of production. Annex 1 provides information on the method water and money values were assessed and the sources of information for different uses of water.

Figure 4 show productivity of different water uses in Luong Tai district and Kim Dong district. The most productive use of water in both the districts is for animal use: about 64 US$ /m^3 in Luong Tai district and 45 US$/m^3 in Kim Dong district, for animal use. The assessment of the amount of water used by animals including drinking, washing, etc, is based on the Vietnamese national standards as actual information on water diverted to or used by the animals was not available.

Small industries and business in Kim Dong districts has higher productivity of water (90 US$/m^3) than in the Luong Tai district (52 US$/m^3). This is due to the higher wages considered in the Kim Dong district (US$1200 per person/year) as compared to the Luong Tai district (US$ 600 per person/year). The factories in Kim Dong district produce higher value products such as car parts and textiles therefore need more skilled labour.

Water productivity of domestic water supplies to towns in the two districts are quite similar respectively 0.55 and 0.47 US$/m^3 for Kim Dong district and Luong Tai district, despite the fact that the methodology used for assessing those values are different. In Kim Dong district the value generated by water supply for domestic purposes is assessed using the reference value provided in the MASSMUS-RAP sheet (that is 10US$/capita/year). Whereas, in Luong Tai district actual amount of revenue collected by the water companies providing domestic water is used as the total value generated.

One element of differentiation for the productivity is linked to the different prices for water supplied. Price of water raises with the amount of water used, it is 2500 VD/m^3 for water use up to 10m^3, 3000 VD/m^3 from 10m^3 to 30m^3, and 3500 VD/m^3 for water use greater than 30 m^3. Because of relatively marginal quality of groundwater in Luong Tai district, surface per capita water used for domestic purposes is (138 l/d/p) in Luong Tai district as compared to Kim Dong district (50 l/d/p).

The difference in the water productivity for villages or individuals is more pronounced – 0.342 US$/m^3 in Kim Dong district and 0.228 US$/m^3 in Luong Tai districts. Different methods in assessing the water use here also are used and can explain the gap.. In Kim Dong district estimates of actual water supply to villages (5000 people) were available, but in case of Luong Tai district Vietnamese standards for individual water use (120l/p/d) were used to assess the water supply to 200 individuals. No villages were considered.

The lowest values of water productivity in the two districts are found in water supply to homestead gardens (0.13 US$/m^3) in Luong Tai district and perennial vegetation (0.03 US$/m^3) in Kim Dong district. The reasons for significantly different values in the two districts for homestead gardens is because of the difference in the unit prices used for assessing values generated – 0.25 US$/$m^2$ in Kim Dong district and 0.0625 US$/$m^2$ in Luong Tai district. Similarly, the difference in the difference in values in water productivity of perennial vegetation in the two districts is due to the way amount of water used is calculated. In Kim Dong districts, the values provided in the RAP sheets (1785 mm per year) are used, whereas in Luong Tai districts values based on part of water requirement for Eucalyptus in the area are used (1000 mm per year).

Value of water productivity of culture fisheries in ponds is the same in both the districts, i.e. 0.64 US$/$m^3$. These values are based on the total amount of water diverted to support fisheries minus 70% that returns to into the canals. However, quality of the return flows is reduced as a result of chemical used to culture fish.

Productivity of water delivered for crop cultivation in Luong Tai district and Kim Dong district is 0.39 and 0.30 respectively. These values are relatively high when compared with other systems in Asia (see figure 5), particularly the irrigation systems in Vietnam – Cau San – Cam Son, Dau Tieng, and Log Hai.

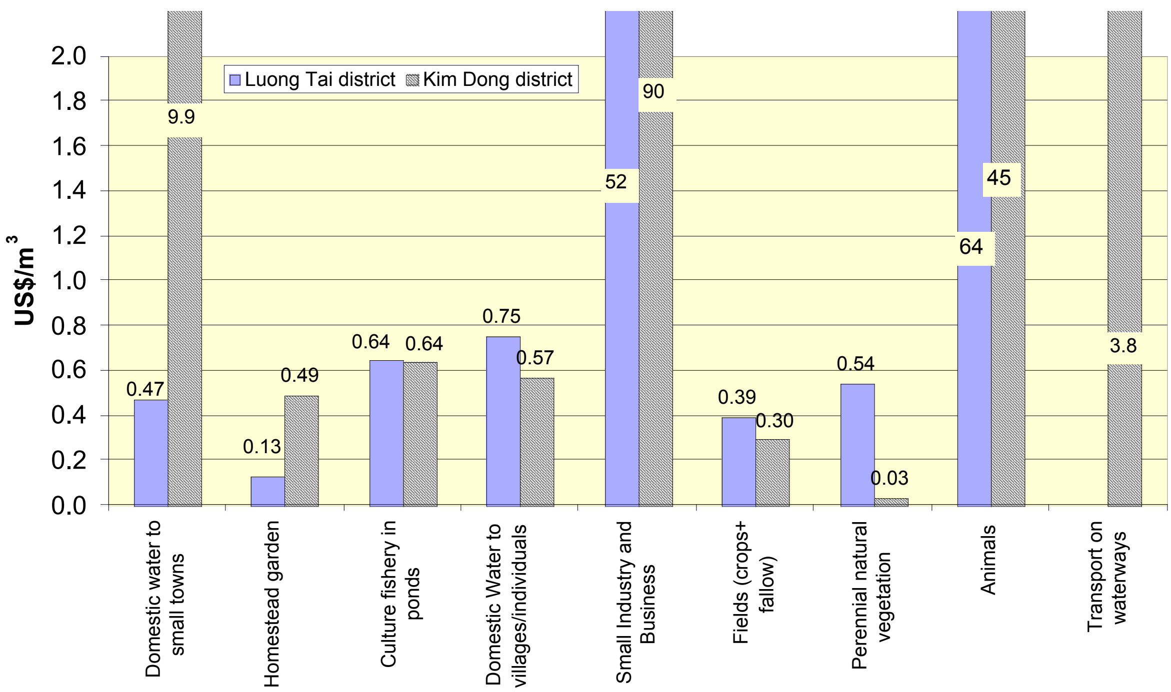

Figure 4: Productivity of different water uses in Luong Tai and Kim Dong districts of BHH irrigation and drainage system

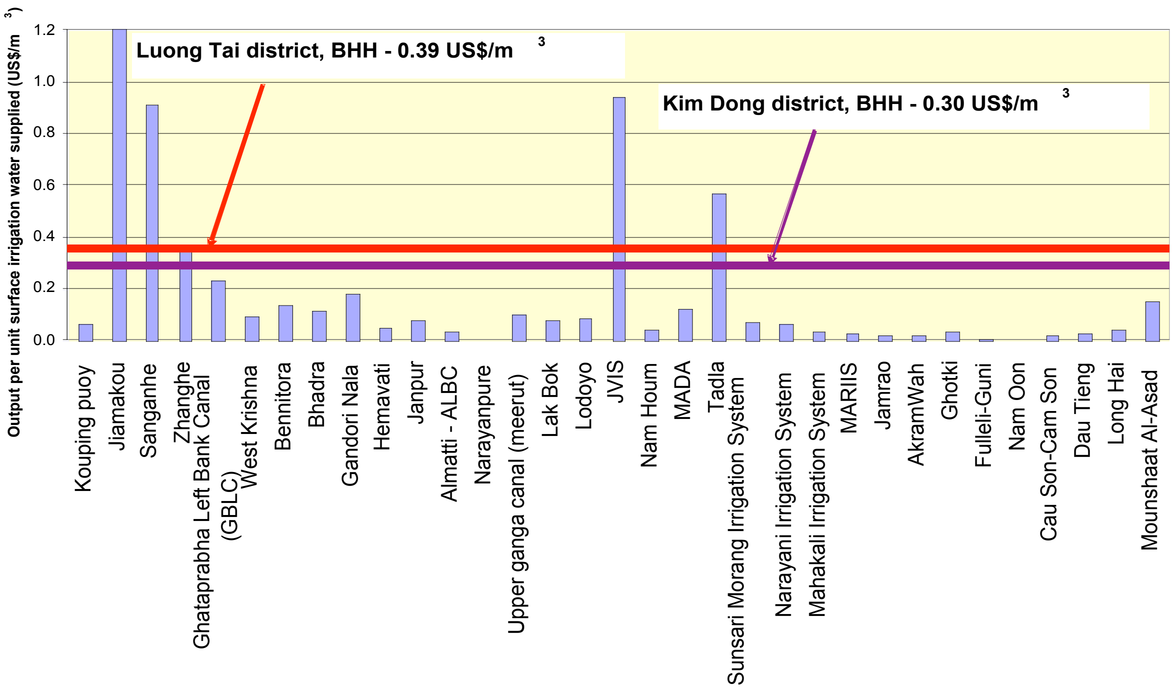

Figure 5: Productivity of water delivered for crop cultivation in different irrigation systems in the world.

Share of water and gross value generated by different water uses

Water supply to different uses was difficult to estimate as the discharges are not measured except for the domestic water supply. Overall water supply to Kim dong district was estimated using the pumping hours, energy used (based on the electricity bills) and pump capacities and efficiencies (taken at 60% as the pumps are 30 years old). The water supply to other uses, such as fisheries and homestead garden was estimated based on the area under each use, the depth of water, and frequency of watering. Water supply to the factories and for domestic purposes is well measured by the water companies. An efficiency of 70% was used to assess water diverted from BHH system to these water supply companies. Annex 1 provides information on the way water supply to different water uses is assessed and table 10a and 10b presents the actual values of these water uses. It is interesting to note that the water balance of the two districts is quite different. The amount of water that is unaccounted for in Luong Tai district is much higher, 37.5 MCM, than in the Kim dong district, 1.51 MCM, which seems to be too low considering the fact that about 200 MVD (US$ 12,500) is spent every year to pump the drainage water out of the system. The low value of the closure term could be due to the inaccuracies in water estimations for different uses.

Figures 6a and 6b show share of water provided to each use and gross value generated in US$ by each use in the two selected districts of BHH. Water supply to crops is the single most water use in both the districts - about 85% and 90% in Luong Tai and Kim Dong districts respectively. The next higher water use in Luong Tai district is by cultured fisheries, which uses 13 % of the total water supply in the district. While crops also generate the highest gross value in US$, 61%, fisheries contributes only 15% of the total US$ generated in Luong tai district. Animals, however, are very productive; they consume only 0.2% of the total water distributed in Luong Tai province and generate about 24% of the gross value.

Table 10a: Water accounting in Kim Dong district for the year 2008

		ANNUAL WATER USED						
		Annual water diverted	water returned to the system	water diverted - water returned	Fraction water use (annual water diverted in MCM/total annual water diverted	Evaporation fraction in the canals (fraction water diverted * total evaporation from the canal network - 1.493 MCM)	Annual water used	Percentage of water use
	Uses of Water	MCM	% of water diverted	MCM		MCM	MCM	%
1	Domestic water to small towns	0.06	80	0.011	0.0007	0.0011	0.0121	0.02
2	Homestead garden	2.00	0	2.000	0.0266	0.0396	2.0396	2.76
3	Culture Fishery in ponds	1.08	80	0.216	0.0143	0.0214	0.2374	0.32
4	Domestic Water to villages/individuals	0.02	80	0.004	0.0002	0.0004	0.0040	0.01
5	Small Industry and Business	0.07	70	0.020	0.0009	0.0013	0.0217	0.03
6	Fields (crops+ fallow)	65.62	0	65.618	0.8712	1.3007	66.9190	90.65
7	Perennial natural vegetation	4.06	0	4.061	0.0539	0.0805	4.1414	5.61
8	Animals	0.79	70	0.237	0.0105	0.0157	0.2530	0.34
9	Drainage/Sewage from the industry	0.00	0	0.000	0.0053	0.0079	0.0479	0.06
10	Transport on waterways	0.40	90	0.040	0.0000	0.0000	0.0000	0.00
11	Environmental flows	1.23	90	0.123	0.0163	0.0244	0.1474	0.20
12	Flood protection services	0.00	0	0.000	0.0000	0.0000	0.0000	0.00
	Total	**75.32**					**73.82**	**100**
	Closure - outflow (total diverted - total annual used)							**1.51**

Table 10b: Water accounting in Luong Tai district for the year 2008

		Annual WATER USED						
		Annual water diverted	water returned to the system	water diverted - water returned	Fraction water use (annual water diverted in MCM/total annual water diverted	Evaporation fraction in the canals (fraction water diverted * total evaporation from the canal network - 1.52 MCM)	Annual water used	Percentage of water use
	Uses of Water	MCM	% of water diverted	MCM		MCM	MCM	%
1	Domestic water to small towns	0.33	85	0.0493	0.0028	0.0042	0.0535	0.0654
2	Homestead garden	1.50	0	1.5000	0.0126	0.0191	1.5191	1.8580
3	Culture Fishery in ponds	48.00	80	9.6000	0.4024	0.6116	10.2116	12.4894
4	Domestic Water to villages/individuals	0.01	80	0.0018	0.0001	0.0001	0.0019	0.0023
5	Small Industry and Business	0.00	70	0.0011	0.0000	0.0000	0.0011	0.0014
6	Fields (crops+ fallow)	68.88	0	68.8838	0.5774	0.8777	69.7614	85.3223
7	Perennial natural vegetation	0.05	0	0.0500	0.0004	0.0006	0.0506	0.0619
8	Animals	0.52	70	0.1568	0.0044	0.0067	0.1635	0.2000
	Total	119.30					81.76	100
	Closure - outflow (total diverted - total annual used)							37.5

Situation in Kim Dong province is a little different (see figure 7a and 7b), where share of water provided to crops is about 91%, but its contribution to the gross value of production is less than 50%. The second biggest user of water in this district is perennial vegetation that consumes about 5.6 % of total water distributed and create only 0.33% of the gross value of production. However, natural vegetation has other benefits such as providing shades and improvements in habitat, which are difficult to quantify. Animals contribute 29% and the revenue from drainage/sewage services provided to factories and other businesses amounts to 5% which form the other main contributors to the gross value of production in the area. Water delivered to animals is only 0.34% and water delivered to the factories and small businesses is about 0.03% of the total water distributed in Kim Dong district.

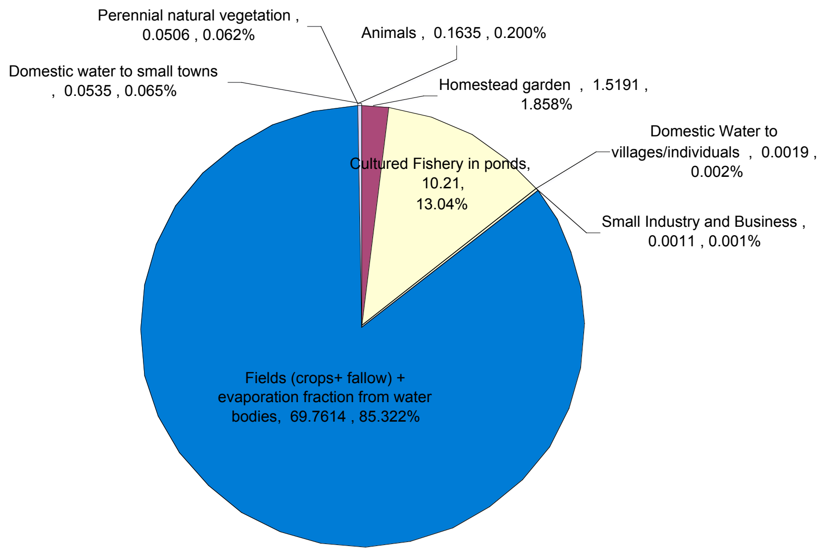

Figure 6a: MCM of water provided to different uses of water in Luong Hai district of BHH

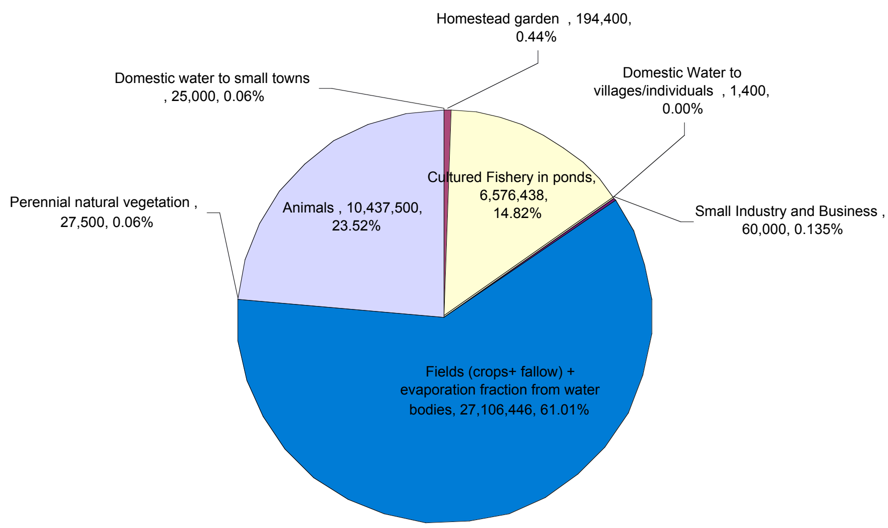

Figure 6b: US$ generated by the different water uses of water in Luong Hai district of BHH

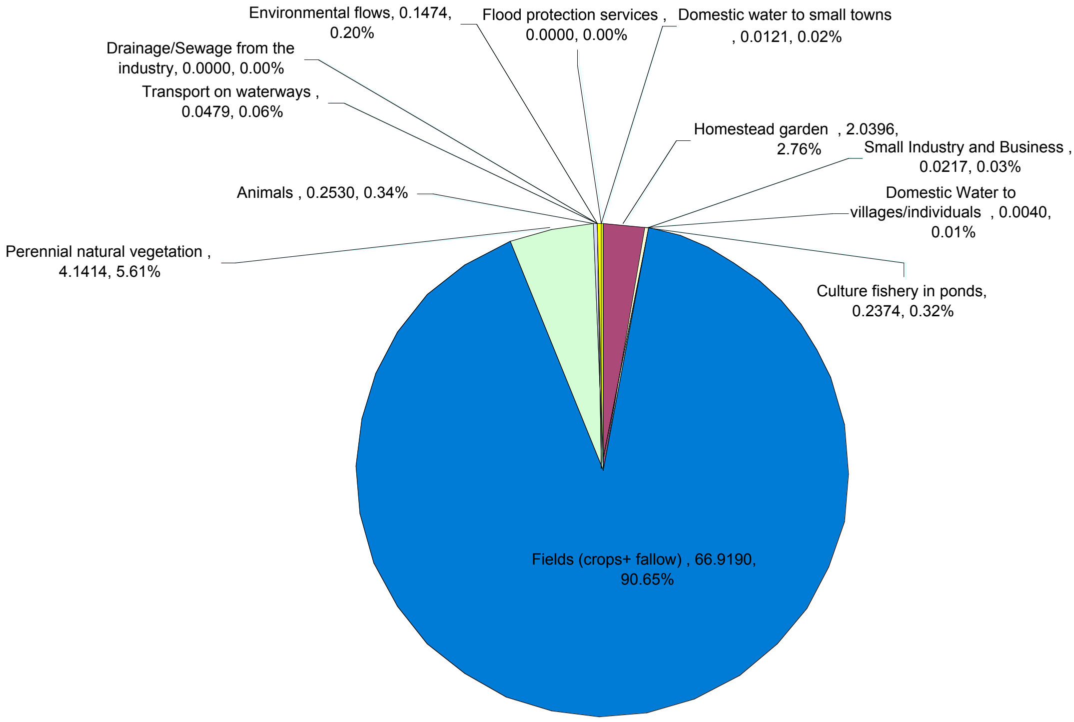

Figure 7a: MCM of water provided to different uses of water in Kim Dong district of BHH

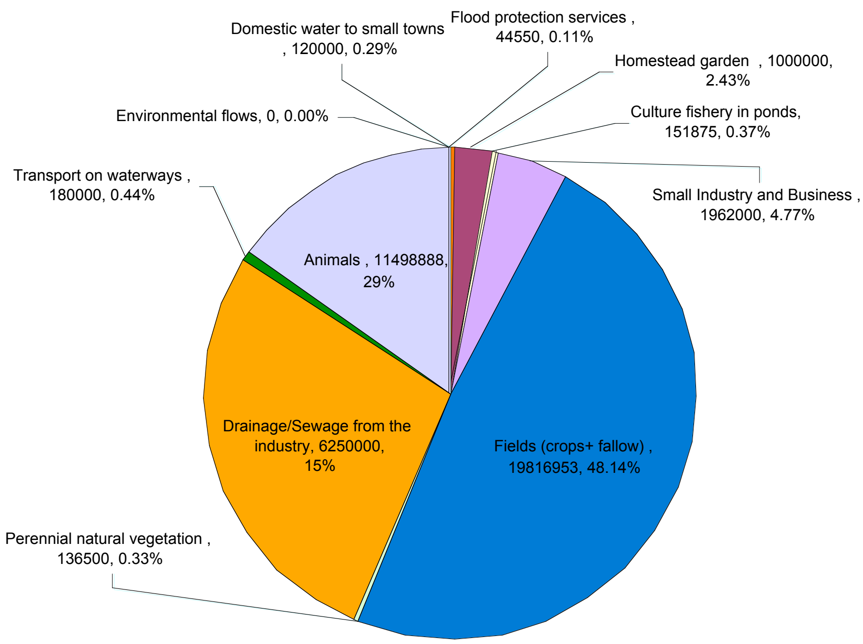

Figure 7b: US$ generated by the different water uses of water in Kim Dong district of BHH

Step 5: Mapping the Cost of Operation

Each service provided by any irrigation or water supply network has a cost related to it. Step 5 of MASSCOTE and MASSMUS maps the service provided and the share of cost to produce this service. The bill for the irrigation management services has to be paid by someone, now or later, for own use or for someone else. It is common to see the taxpayer paying part of the entire bill for irrigation management at the investment. It is also common to see the taxpayer paying for Management, operation and maintenance (MOM), but this modus operandi cannot last for long.

Therefore, it is a major responsibility of the management to organize effectively the flows of money for producing the services (MOM).

In BHH, like many irrigation systems in the world, it is almost impossible to assess the costs associated with different services. Irrigation managers do not keep itemised account of all the costs. The cost estimates of Kim Dong province is provided in the figure 8a. Although this expenditure and revenue estimates are itemised, it is still not possible to assess the share of MOM costs for producing different services in the districts. The expenditures and the revenue is basically a theoretical exercise because almost full cost of management, operation and maintenance is covered by the budget provided by the State. Irrigation and drainage service fee, which was abolished in 2008, provides basis for budget estimates, considered as potential revenue and is presented in figure 8b. Water users do not pay any money to the management of the district except for the services provided for draining the sewage water from the industries and the small businesses.

Step 6: Service to Users

The analysis of service to users is central in the MASSCOTE approach through the concept of service oriented management (SOM). The central idea is that “service” must be agreed upon between the service provider and the service receiver. Although an inventory of different services is already made in Step 0, this step (Step 6) is focused more on the importance of each of the current services as well as the multiple water services required in the future so that the vision of the irrigation scheme can take into account the future needs. Moreover, the improvements mapped in the next steps of MASSMUS (from step 7 to 10) should also be based on the multiple services an irrigation system is foreseen to provide to different users.

From Service to Vision

Vision for BHH made as part of the MASSCOTE application in May 2009 did not include multiple uses of water in it. However, after applying MASSMUS, the managers are convinced that multiple uses should be part of the vision of BHH. The vision statement as proposed by the experts and the managers is:

> *A modern, multiuse and financially self sufficient irrigation and drainage scheme that contributes to the national food security and socio-economic development while ensuring environmental sustainability.*

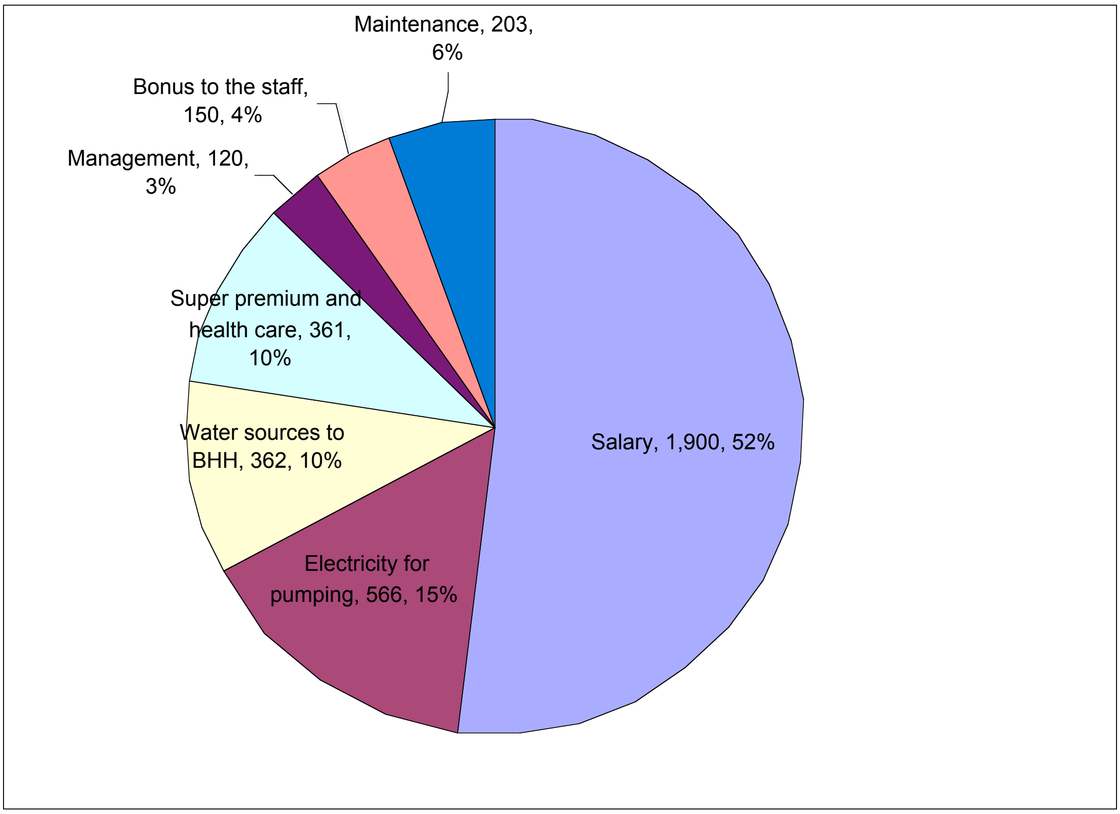

Figure 8a: MOM costs in Billion Vietnamese Dong for providing services in Kim Dong districts in the year 2008.

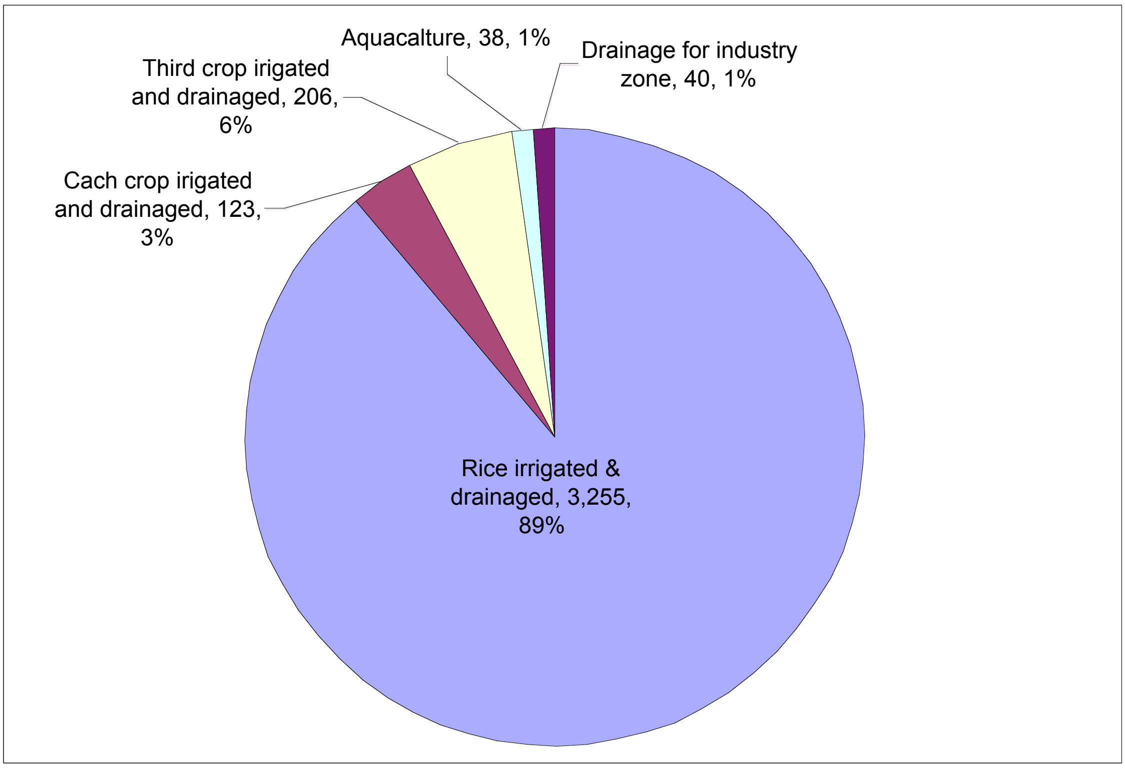

Figure 8b: Potential and actual (drainage for industries) revenue in Kim Dong districts in Billion Vietnamese Dong in the year 2008.

Concluding Remarks and the way forward

The MASSMUS module was tested in the two districts, Luong Tai district and Kim Dong district, of Bac Hung Hai irrigation and drainage scheme in Vietnam. After initial difficulties of the managers to grasp the idea and identify ways to quantify water supply from the different uses, the water accounting in RAP was successfully carried out. The Module was found relevant and applicable by the experts - from Vietnamese academy of water resources and water resources planning institute as well as the managers of the irrigation scheme. Application of MASSMUS module served as an eye opener for the managers of the scheme, in helping them realise the extent of water services they are providing to different uses in the command area and the gross value of production generated by these services.

Although, it was difficult to get correct values of water supply to different uses as no water measurement takes place in the command area, it was still possible to roughly estimate water used by each service. Similar observations were made in case of assessing gross value of production. For example, capture fisheries in canals and streams was the most difficult water use for which gross value of production was impossible to quantify as no one knew how much fish is captured every day. Moreover, it is difficult to assess water productivity of some uses because i) of the use of standard values instead of actual values. For example, for drinking water supply to the villages and individuals, the national and international standards may be much higher than the actual water use, and ii) other water sources are available and there is no way to find out how much water is used by the other sources.

Some of the questions and the indicators need to be improved. For example, currently the service to different uses is evaluated in terms of definition and in terms of achievement. It was felt by the experts, that the two should be combined into one.

Application of MASSMUS module, in particular water balance, is a bit more complicated as compared to MASSCOTE methodology and water balance in RAP. People (managers/consultants) need more training in the application of the module.

The next steps for the MASSMUS module will be to update the MASSMUS RAP sheet; and test it again in some other systems.

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Annex 1: Basic information on water and value assessment of different water uses in BHH

Water use	Sources of information	Discharge or volume assessment/ measurement	Value generated assessment
Domestic water to small towns	Water supply companies (water meters)	water supply is measured but drainage/sewage isn't measured	In case of Kim Dong the value is generated based on the values provided in the table in RAP sheet (Renwick et al – US$ 40/person/year). In Luong Tai district it is the total revenue collected by the water companies.
Homestead garden	Irrigation managers; established tables in MASMUS RAP sheet	no water measurement - estimates from information from farmers; only vegetable gardens are considered: water used was estimated as irrigation depth (5 cm) x area x number of irrigation in a year (10).	assessment based on income per year per m^2 or per ha. In case of Kim Dong district the income is considered as 0.25 US$/$m^2$, whereas in case of Luong Tai district it is only 0.06 US$/$m^2$ (or 10 M Vietnamese dong/ha).
Culture Fishery in ponds	Irrigation managers; interviews with fish farmers;	no water measurement - estimates by irrigation managers (based on information collected by fish farmers and official records of area under fish farms)	assessment based on the farmgate prices of fish, the yield per ha, and/or the income per ha per year.
Domestic Water to villages/ individuals	Water companies; irrigation managers	when water is supplied by a water company, it is measured. Otherwise assessed by the irrigation managers based on water use criteria in Vietnam (120 l/p/day).	In Kim Dong district assessment is based on the actual revenue collected by the water companies, or price x water used. In case of Luong Tai districts where individuals are getting water from the canals and are not paying any revenue, water price per m^3 (2500 VD/ m^3) established by the water companies is used.
Small Industry and Business	Water companies; Irrigation managers	volume is measured if supplied by water companies. Estimated by the irrigation managers based on the information gathered from the small businesses	based on the jobs provided by the small businesses x the annual salaries (US$ 1200/person/year in Kim Dong district and US$ 600/person/year in Luong Tai district.)
Fields (crops+ fallow)	Irrigation managers	estimated water supply based on the pumping hours, capacity, and efficiency (60%); and/or other estimates such as water levels.	based on farm gate prices of different crops, yields and area under each crop
Perennial natural vegetation	Irrigation managers; established tables in MASMUS RAP sheet	no water measurement - estimates from information from irrigation managers (1000 mm/year) for Luong Tai district; and from tables given in RAP sheet (1785 mm/year) for Kim Dong district. In Luong Tai district the managers took Eucalyptus as a representative tree and assessed based on the	estimated based on the income /ha/year, which is US$ 600 for Kim Dong district and US$ 550 for Luong Tai district.

		literature the irrigation needs of Eucalyptus in the area. In Kim Dong district, the managers decided to rely on the water requirement for trees provided in the RAP sheets.	
Animals	Irrigation managers	No measurement – estimates by the irrigation managers based on the Vietnamese standards for water requirement for animals (big animals – cattle, buffaloes = 35 l/head/d; medium size - pigs, goat, sheep = 25 l/head/d; small size - chicken, duck = 0.25 l/head/d)	price of the animals x number of animals; (big animals – cattle, buffaloes = US$ 400 per head; medium size - pigs, goat, sheep = US$ 120 per head; small size - chicken, duck = US$ 2.5 per head)
Drainage/Sewage from the industry	Irrigation managers	no measurement – estimates by the irrigation managers based on percentage of supplied water returning to the canals, and percent rainfall discharged in the canals	amount of money charged by the agency for drainage discharge into the canals. This is based on the area of the factories (US$ 856/ha/year).
Transport on waterways	Irrigation managers	no measurement – estimated on the basis of minimum depth maintained for transportation	based on the number of jobs (150 jobs) created/provided and the salaries (US$ 1200 per person per year).
Environmental flows	Irrigation managers	no measurement – estimated on the basis of minimum depth maintained for diluting sewage/drainage water.	none
Flood protection services	Irrigation managers	no measurement	estimated based on the damage done by floods couple of years ago. 50 ha were flooded with 40% productivity loss.