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RESEARCH REPORT

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The Impact of Irrigation On Aquatic Wetland Resources - A Case Study of That Luang Marsh, Lao PDR

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This study assesses the impact of irrigation on That Luang Marsh (TLM) in Vientiane, the capital city of the People's Democratic Republic (PDR) of Laos. It was carried out by Phouphet Kyophilavong from the Faculty of Economics and Business Management at the National University of Laos.

The study finds that the economic benefits provided by the marsh (particularly in terms of the fish it supplies to local people) far outweigh the benefits provided by the extraction of water for irrigation. As extraction of water for irrigation is threatening the ecology of the marsh and its ability to maintain a viable stock of fish, it is clear that the amount of water extracted for irrigation should be reduced. The report recommends that a minimum level for the water in TLM should be set to ensure the conservation of its precious wetland ecosystem. The report finds that, on balance, this would have a positive impact on the livelihoods of local people. This means that the conservation of the marsh makes good economic sense.

To help the farmers who would be negatively affected by these measures, the report shows how they could be trained to use irrigation water more effectively, grow alternative crops that require less water than rice, catch fish and collect vegetables.

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The Impact of Irrigation on Aquatic Wetland Resources – A Case Study of That Luang Marsh, Lao PDR

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October, 2008

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All the conclusions and recommendations in this report are those of the author and do not necessarily reflect the views of EEPSEA. The author alone is responsible for any errors in this report.

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LIST OF ABBREVIATIONS

AWR	Aquatic Wetland Resources
ha	Hectare
hh	Household
IDVC	Irrigation Division of VC
IUCN	International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
kg	Kilogram
LARReC	Living Aquatic Resources Research Center
m	Meter

m^3	Cubic Meter
mil.	Million
mm	Millimeter
NGD	National Geographic Department
PRA	Participatory Rural Assessment
TLM	That Luang Marsh
UCS	Urban Cleaning Service
VC	Vientiane Capital
WUG	Water Using Group

THE IMPACT OF IRRIGATION ON AQUATIC WETLAND RESOURCES – A CASE STUDY OF THAT LUANG MARSH, LAOS

Phouphet Kyophilavong

EXECUTIVE SUMMARY

This paper analyzes the impacts of irrigation on Aquatic Wetland Resources (AWR), using That Luang Marsh (TLM) in the Vientiane capital, Laos, as a case study. A review of literature on the topic revealed that there were very few empirical studies on the interface between irrigation water use and AWR use. Therefore, this paper attempts to analyze the impact of smallholder irrigation on AWR in TLM using various approaches namely, the Participatory Rural Assessment (PRA) method, to identify general issues in irrigation and wetland management; a cost-benefit analysis to measure the net benefits of rice production and AWR; the building of a simple water balance model; and using experts' assessments to identify the impacts of irrigation and the setting of a minimum water level requirement for TLM.

The results show that despite there being an irrigation project in TLM, the total net benefit from its AWR is substantially higher than the net benefit from irrigated rice production during the dry season. Over-use of water for irrigation will reduce AWR by 12.5% in the dry season, equivalent to US$ 58.28 thousand. The water level in TLM in some months during the dry season is under the minimum water level requirement for AWR. If the minimum water level requirement for AWR is set at 0.5 m in TLM, total rice production in TLM would decrease by 20.3% (US$ 21.72 thousand) while the net benefit from AWR would increase by about 10% (US$ 48.56 thousand). It is clear that the revenue gain from AWR would be higher than the loss in rice cultivation output if a minimum water level were to be set. This result shows that AWR play a more important role than rice cultivation during the dry season; therefore, policy-makers should give priority to AWR in water distribution decisions.

1.0 INTRODUCTION

1.1 Research Problem

Wetlands are complex ecosystems that provide many ecological, biological, and hydrologic functions that are of great value to society. In recent times, a greater scientific understanding of the role of wetlands in the sustainable management of ecosystems and improvement of rural livelihoods has increased public appreciation of wetlands. As a result, society in general is increasingly valuing wetland conservation over converting them for private economic use. However, individual incentives to support the conservation or conversion of wetlands are subject to external economic effects called externalities. The proper treatment of these externalities is the central issue in the efficient and socially responsible management of a wetland. Policies designed to balance public interests in wetlands with private benefits from wetland conversion to other uses have been contentiously debated (Heimlich et al. 1998; Mole

2005).

It is widely recognized that large-scale irrigation is detrimental to wetlands as it tends to drain the latter. How other types of irrigation including small-scale irrigation affect wetland resources are, however, not yet fully explored in the literature, particularly in the short and long term (Hector, Priyanie and Huber-Lee 2005). This study is thus important as most of the irrigated farmlands in TLM are small-scale rice farms.

In spite of the negative impacts of irrigation on wetland management, there are also some positive 'feedback' effects of irrigation in terms of increased income and poverty alleviation in the areas surrounding the wetlands. Here, the long-term labor shifting effect will counter the short-term negative effects by allowing the shifting of the excess labor from the aquatic base to agriculture and other production-related activities in the irrigated area (Heimlich et al. 1998). These complex feedback issues, which are also related to positive multiplier effects (or environmental externalities), have not been sufficiently examined in past studies particularly the quantification of the external effects involved in the interaction between wetland and small-farm irrigation water uses (Lankford 2000; Molden and Sakthivadivel 1999; Molden 1997). Therefore, in order to find a way for wetlands and irrigation to co-exist, it is important to identify the wetland and irrigation management issues and the impact of irrigation on wetland resources.

That Luang Marsh (TLM) is an urban wetland, located near Vientiane Capital (VC). It plays an important role for VC residents in term of direct and indirect benefits. However, the demand for water from TLM for irrigation is great during the dry season. This has led to a reduction in the volume of water in TLM with a corresponding decrease in the quality of AWR in the marsh. However, very few studies on this problem in TLM have been conducted. Thus, TLM represented the ideal case study to examine the connection between wetland conservation and irrigation.

1.2 Objectives of the Study

The main purpose of carrying out the study in the TLM is to generate an improved knowledge base on the impacts of irrigation on AWR.

The specific objectives of the study are as follows:

1. To measure the profitability of rice farming in TLM.

2. To estimate the net benefits obtained from the AWR in TLM.

3. To estimate the impact of irrigation on AWR.

4. To identify the minimum water level requirement to maintain the AWR in TLM in good condition and measure its impact.

The overall framework of this study, and in particular, how the four objectives of this study are interlinked, is shown in Figure 1 below.

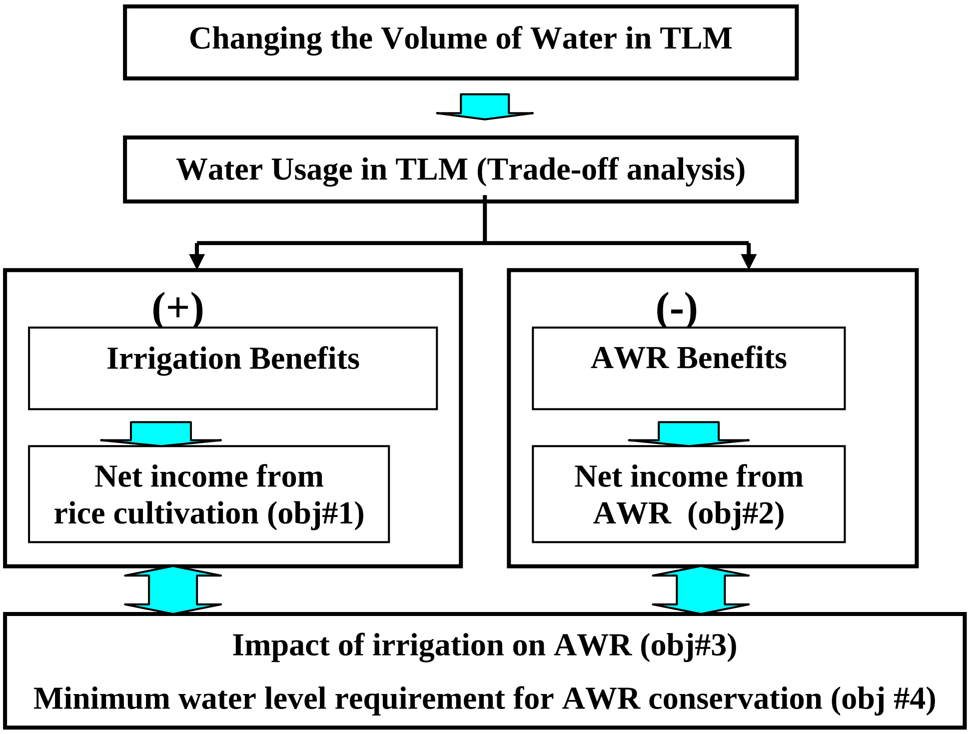

Figure 1. The conceptual framework of the study

1.3 Scope of the Study

This study concentrated on the diversion of water out of the wetland for agricultural purposes, and analyzed the direct economic externalities associated in the process.

The geographical and analytical scope of this study is as follows:

a) The scope of this study site was limited to TLM, in VC, covering all 17 villages located around the marsh.

b) Analyzing the impacts of irrigation on wetland resource use (namely, agricultural water diversion out of the wetland) and exploring the effects of these on the livelihoods of the communities living in the vicinity of the marshland area.

c) Analyzing the externalities resulting from irrigation for rice production.

d) Analyzing the trade-offs between the benefits of using water for irrigation (in terms of improving agricultural productivity) and the benefits of using water to conserve AWR (such as fish, non-fish animals, and vegetation).

e) Analyzing the demand for water (usage) in irrigation.

1.4 Literature Review

There are few studies on the impact of smallholder irrigation on AWR in developing countries. Smakhtin (2002) suggested a framework to analyze the water requirements of aquatic ecosystems and environmental aspects associated with irrigated agriculture in river basins. Hector, Priyanie and Huber-Lee (2005) reviewed the literature on the effects of agricultural irrigation on wetland ecosystems in developing countries. The researchers concluded that the use of water for irrigation had both positive and negative effects on wetland resources, and the sum total of these effects was not clear. Meanwhile, Adams and Hoon (1998) used a hydrological model and a crop yield model to measure the trade-offs between agricultural productivity and the conservation of endangered species in Klamath Basin, Oregon. They found that farmers could sometimes adjust their irrigation decisions to offset water shortages. However, there were costs to agricultural output. Chong (2005) assessed the economic value of the Stoeng Treng RAMSAR site in Cambodia in order to improve wetland management. This study found that wetland resources were essential to livelihood, worth an average of US$ 30,000 per household per year. Fishery was more valuable to poorer households than the wealthier ones. Janekarnkij and Mungkung (2005) assessed the economic value of the Krabi river estuary RAMSAR site as a marine tourism center by using market prices and the benefit transfer approach.

There are also some studies concerning wetland values in Laos. Gerrard (2004) measured the economic value of TLM by using secondary data from Vientiane Capital (VC) and identified the impact of urban planning on the ecosystem in TLM. The economic value of TLM (direct and indirect values) was under US$ 5 million per year to the people in VC. This study demonstrated that the loss of wetland resources would have a large impact on local communities, in particular on the poorer households relying on the wetland’s resources. Phonvisai (2006) also measured the economic value of TLM by reviewing the environmental impact of existing land use changes and policies on the wetland’s ecosystem values. This study found that the changes in land use were increasing and these had a negative impact on wetland resources. Finally, Ngun-Khoa, Smith and Lorenzen (2005) measured the impact of irrigation on inland fisheries by using an integrated and participatory approach to environmental impact assessment. They found that the overall impact on livelihoods was expected to be positive in Laos because the majority would benefit from irrigated farming. However, the landless or land-deficient households, which were heavily dependent on fishing, would be at risk of loss of livelihood.

1.5 Methodology

The main objective of this study was to generate an improved knowledge base on the impacts of irrigation on AWR by way of doing a trade-off analysis on the usage of water for irrigation and for AWR conservation.

To do this, we first estimated the benefits of irrigation and AWR from primary data and secondary data. Then, we estimated the volume of irrigation water used and the water stock of TLM by using a simple water balance model. Finally, we identified the minimum water level requirement in order to maintain the AWR of TLM in good condition. We also identified the water usage demand in irrigation.

We used various methodologies to meet the study objectives. Firstly, the Participatory Rural Assessment (PRA) and related participatory assessment techniques were used in five villages in order to get a general picture of the current situation in TLM. We also interviewed the heads of 17 villages and leaders of the "Water Using Groups"[1] (WUGs) and also interviewed relevant government agencies.

Cost-benefit analysis was used to estimate the profitability of rice farming in TLM. A market-based household income survey was used to estimate the direct benefits from its AWR. The measurement of the impact of irrigation on the AWR and the identification of the minimum water level requirement for AWR conservation in TLM was done as follows: First, the net benefits from irrigation and AWR were estimated. Next, a water balance model for estimating the water stock in TLM and the volume of water used for irrigation was estimated in consultation with an irrigation expert, a hydrologist. Finally, the minimum water level requirement for AWR and its impact on AWR were determined in consultation with fishery experts.

1.6 Data Collection

To meet the study objectives, both primary data and secondary data were collected. Secondary data in relation to irrigation, wetland management, aquatic wetland resources, water and land use, and socio-economic variables of households in TLM were gathered from leading government and related agencies in VC. The key government agencies visited were as follows: the Ministry of Agriculture and Forestry (MOAF); Irrigation Division of VC (IDVC); Science, Technology and Environment Agency (STEA); National Land Management Authority (NLMA); Water Resources Coordination Committee (WRCC); Living Aquatic Resources Research Centre (LARReC); Mekong River Committee (MRC); and International Union for the Conservation of Nature (IUCN).

We employed stratified random sampling techniques for the selection of 317 households for the household survey from 17 villages located around TLM (Table 1). Checklists were prepared for the key informant survey, and semi-structured questionnaires for the household survey. The checklists and questionnaires were finalized in consultation with the concerned institutions like the IDVC and LARReC, and the community leaders of villages. The household survey covered two target household groups; the rice cultivators and landless villagers, both of whom catch fish and non-fish animals, and collect vegetation. The paddy (rice) farmers were categorized under irrigated and rain-fed farms. The household survey covered both small-scale and large-scale farmers.

The household survey questionnaire was pre-tested in a pilot survey to evaluate its effectiveness. The feedback from the pre-test was used to revise the questionnaire. The interviewers were fifth-year undergraduate students who received guidance from lecturers from the Faculty of Economics at the National University of Laos (NUOL).

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[1] The WUGs are local organizations for using irrigation water in TLM. There are three WUGs in TLM, the Mueng Noi Group, the Xieng Da Group, and the Non Khor Neua Group. The main duty of each group is to maintain irrigation canals, distribute irrigation water, and collect water fees.

Table 1. The sampling sizes

Target survey household groups		**Dry season**	**Rainy season**
Rice farmers	Large-scale	77	52
	Small-scale	128	111
	Sub-total	205	163
Landless peasants		112	154
Total		317	

2.0 THE PROFILE OF THAT LUANG MARSH

2.1 Socio-economic Characteristics

TLM is located close to VC[2]. The wetland system combines freshwater, marsh, seasonally-flooded grasslands, and shrub lands. It covers an area of around 16 square km[3], and collects water that drains from VC and the surrounding suburban areas (Gordon 1996). Wetlands and marsh areas in and around the city are important physical features and serve key hydrological functions such as providing water for farming in the surrounding areas of the marsh, flood control, maintaining river flow during the dry season, the purification of wastewater from the surrounding urban areas, and being a source of aquatic resources for the communities of the wetlands (JICA 1990). TLM serves as a natural breeding ground for fish and other edible aquatic resources that support the local residents, particularly the landless communities residing around the marsh. A map showing the location of TLM is given in Figure 2.

There are 17 villages around the TLM area with 43,500 people (7,731 households), representing about 6% of the total population of VC in 2006 (Appendix 1). The number of people living around the marsh has more than tripled over the 1990s, from just over 2,000 households in the early 1990s to more than 7,000 in 2006. Most of the people in the 17 villages are employed in the private sector (54%), followed by the government sector (15%), and rice cultivation (13%). About 8% of the households do not rely on agriculture for income, and it is likely that they survive by catching fish and collecting aquatic produce from the marsh area (Appendix 2).

The socio-economic demographics of the sampled households are shown in Table 2. Males make up about 50% of the total sample population and the average age is 48 years. The average household has lived in the TLM for about 32 years and consists of five persons.

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[2] In 2005, there were 695,473 people (125,670 households) living in VC.

[3] As estimated by the National Geographic Department in 2006. According to Gordon (1996), the marsh area is roughly 20 km^2 and is part of the TLM Basin.

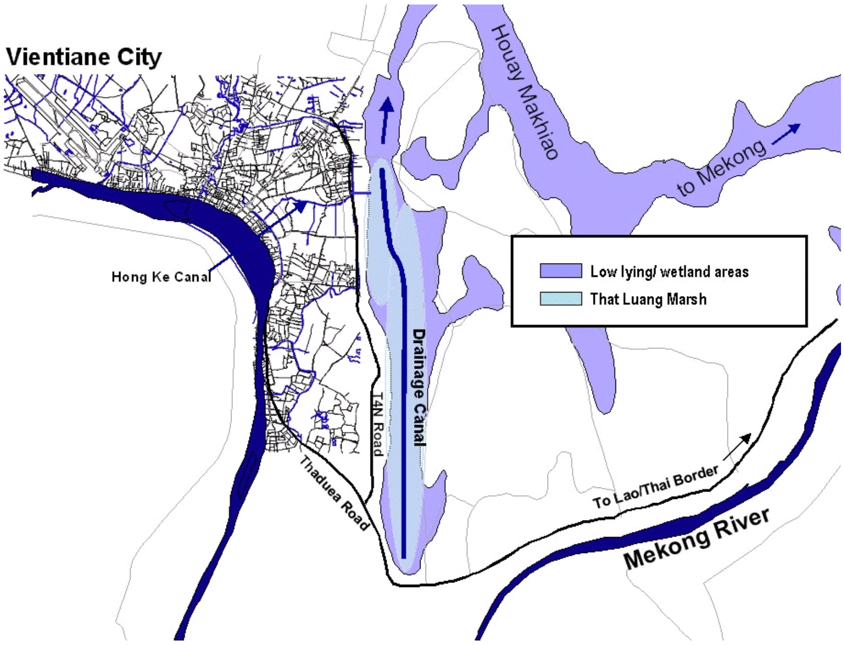

Figure 2. Map showing VC and That Luang Marsh

Table 2. Socio-economic demographics of the sample

Demographic Variables	Unit
Average age (years)	48
Male (%)	49.43
Average household size (no. of persons)	5.41
Average duration of residence in the TLM area (years)	32.2
Have own house (%)	94.6

Source: household survey data

2.2 Land Use Changes and Water Scarcity

2.2.1 Conversion of marshland

Until the 1970s, TLM was covered mainly by forest. At that time, the Governor of Vientiane Capital declared that land for rice cultivation in the wetland would be made available to anyone who wished to clear it. In order to facilitate paddy farming as well as to reduce flooding in the city, two drainage culverts were also installed, at the north and south ends of the wetland. By the 1980s, 700 ha of the marsh had been put under rice cultivation, and in 1986, a further drainage canal was constructed throughout the entire wetland (PRA). This new canal had the effect of changing the natural water flow, diverting the TLM outflow from flowing directly into the Mekong south of the marsh to flowing north through the Houay River. This had the effect of lowering the water level on either side of the canal and facilitating dry season irrigation. As a result, large additional portions of TLM were converted to farmlands. Today rice cultivation covers up to 1,400 ha of the wetland[4].

There are also vegetable gardens and a number of small, medium and large fish farms located along the margins of the wetland. Urban expansion and development projects have also involved the reclamation of large areas of marsh for industrial and residential construction, and for infrastructure. In 1999, the T4N Road, running along the western side of TLM, was improved. This has led to the growth of shops, businesses, and residential houses along the road (Gerrard 2004).

2.2.2 Development projects in TLM

About 37% of the land area in TLM is privately owned by individuals (see Appendix 3) while the rest of the land is public property. The government has been very interested in developing TLM and has encouraged investors. Table 3 shows the various development projects in TLM. According to the PRA, these development projects are viewed unfavorably by the villagers because they have significant negative impacts on rice productivity, irrigation system management, and wetland resource management in the marsh.

Table 3. Development projects in TLM

Year	Project Development
1975	Central canal through the wetland, opening up the area for rice cultivation
1980	Agricultural expansion - two drainage culverts were installed
1985	Non Kor pump irrigation built
1986	Drainage canal constructed through the entire wetland
1993	Wastewater stabilization ponds built (Wastewater Management of TLM project)
1998	Three garment factories built
1999	T4N road constructed alongside the TLM
2000	Open market and housing project
2002	Mueng Noi pump station built
2003	National Convention Center for the ASEAN Tourism Forum built

Source: modified from Phonvisai (2006)

2.2.3 Land use in TLM

VC has a master plan, called the VC Master Plan. It incorporates a zoning system and development control procedures. However, the plan has not been well

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[4] There are two sources of information on the land area of TLM. Firstly, in Gordon (1996) was 20 km^2 (about 2,000 ha). Secondly, the estimation by the National Geographic Department was 16 km^2 (about 1,600 ha) (personal communication with Mr. Saiyasone, Geographic expert, National Geographic Department, February 2007.)

executed and has, in fact, been modified (Phonvisai 2006). According to interviews with relevant government agencies, the land measurement of TLM has yet to be officially done. Therefore, the exact land use categories are not known. In order to investigate the changes in land use in TLM, we asked the National Geographic Department (NGD) to assess the land use situation in TLM (see footnote 4). According to the NGD, about 85% of the total TLM area is covered by water during the rainy season.

During the dry season, 87% of the total area of TLM is used for rice fields. However, it is important to note that not all the rice fields have been used for production of rice due to water scarcity. About 10% of the total area consists of swamps, ponds, and canals which provide fish, non-fish animals, and vegetation for local communities. Some ponds in TLM are open access, but some are private property. Due to weak law enforcement and monitoring of land use as well as a high demand for land in VC, some areas in TLM have been turned into residential settlements (1.6%), and factories and stores (1.1%) — this trend is becoming stronger.

Table 4. Land use in TLM (dry season, 2006)

No.	Land use	Area (ha)	Share (%)
1	Swamps	65.91	3.93
2	Ponds	68.00	4.05
3	Canals	29.00	1.73
4	Rice fields*	1434.10	85.47
5	Grass	33.54	2.00
6	Roads	1.80	0.11
7	Settlements	26.88	1.60
8	Factories and stores	18.60	1.11
	Total	1677.83	100.00

Sources: National Geographic Department, Prime Minister's Office (estimation from Vientiane city map (updated in 2006); * = rice cultivation area estimates obtained from village statistics.

2.2.4 Water scarcity and water use conflicts

In the past, TLM had rich water resources. However, today the demand for water for irrigation has increased in the dry season, but the water supply is limited. According to the PRA, water scarcity has become a problem since the VC government started to convert parts of TLM into agricultural land, destroying huge land forests, floating forests, and ecosystems in 1985. Since then, people have continued to destroy forests to establish rice fields in the area. Water scarcity has become worse after the new irrigation pump at Mueng Noi station was built in 2002, creating an even higher demand for water for irrigation (PRA).

The total rice-growing area at TLM is 1,434 ha (Appendix 8). Due to flooding during the rainy season, only 30% of the total rice area is used then. On the other hand, only 54% of the total rice area is used during the dry season due to lack of irrigation water. As the demand for water for irrigation exceeds the water supply, the quantity of water in TLM has decreased, leading to the decline of its AWR. This has led to a conflict between the farmers and fisherfolk. Despite there being a law on water and land use, enforcement is weak. In addition, the fisherfolk are poor people who have little power to negotiate with the wealthier farmers.

2.3 Water Stock and Irrigation Water Use in TLM

From our interviews with concerned government agencies, we learnt that data on water levels and quantities in TLM is not available. In order to identify the water uses in TLM, a simple water balance model as done by Molden (1997) was built. The basic form of the water balance model is illustrated in Figure 3 below, which clearly shows the different uses of water in a closed wetland system.

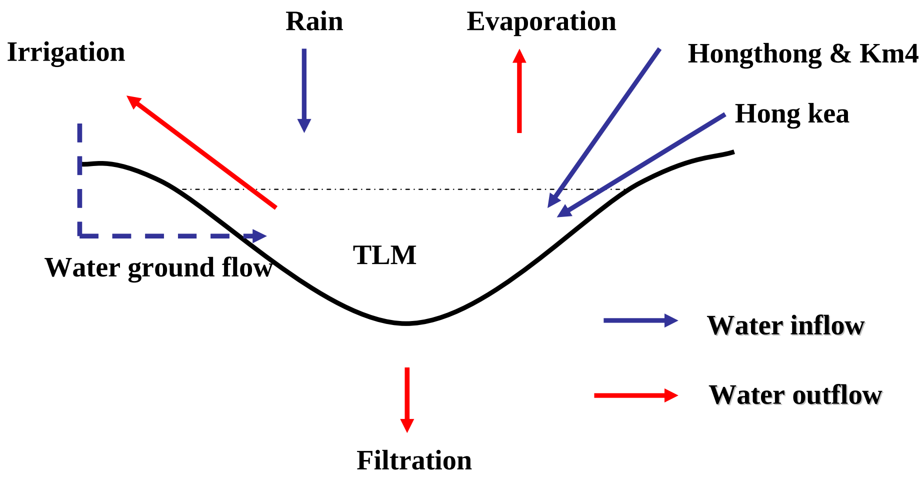

Figure 3. Water balance model for TLM

Notes:
(1) Hongthong and Km4 are the pump irrigation stations which extract water from the Mekong river and pump it into TLM. Hongkea is the wastewater canal from VC.
(2) Filtration refers to the seeping of water into the ground. It is a natural process.

2.3.1 The water balance formula

The hydrological state of TLM was assessed following the method used by Mitsch and Gosselink (2000). We first defined the water budget of the wetland, and then the capacity of the wetland to store water. The balance between water storage, inflows and outflows, as illustrated in Figure 3, was expressed in the four equations given below. Equation 1 shows the water stock (V) in TLM; this is the difference between total water inflow (TI) and total water outflow (TO). Equations 2 and 3 refer to the sources of water flowing in and out of TLM. Equation 4 shows that the water level is dependent on the volume of the water in the marsh and the area of the marsh.

$$V = TI - TO \qquad \text{(Equation 1)}$$

where,

V : volume of water stored in the marsh (m^3)

TI : Total water inflow (m^3)

TO: Total water outflow (m^3)

$$TI = \sum I_n \qquad \text{(Equation 2)}$$

$$TO = \sum O_n \qquad \text{(Equation 3)}$$

where,

I_n : n source of water inflow (m^3)

Q_n: n source of water outflow (m^3)

$$d = \frac{V}{A} \qquad \text{(Equation 4)}$$

where,

V : Volume of water stored in the marsh (m^3)

A : Area of marsh (m^2)

d : Water level (m)

2.3.2 Data sources and assumptions

The water balance analysis was done based upon already existing hydrological data from various sources. The details of the data sources are shown in Table 5.

There are six sources of water inflow for TLM. We estimated the volume of water pumped from the Km4 and Hongthong pump stations based on their electricity bills. The irrigation expert from IDVC estimated that only 10% of the water from the two pump stations flows to TLM due to the long distance between them and TLM. The inflow quantities of wastewater (purified and unpurified) and water from precipitation were provided by the Urban Clearing Project (UCP) and Weather Forecast Center (WFC) respectively. From our consultation with the irrigation expert, we assumed that 10% of the rainfall in VC flows into TLM. The expert further estimated that about 20% of irrigation water actually returns to TLM.

There are five sources of water outflow from TLM as shown in Table 5. The water outflow from the Non Kor and Mueng Noi pump stations were estimated from their electricity bill. The evaporation estimates were obtained from the Mekong River Commission (MRC 2005) and infiltration figures were from Vivathnakun (2000). As we could not estimate the amount of water extracted by private pumps and leakages, we treated them as a residual variable in our water balance model.

Table 5. The description of variables and sources of data

Water Inflow

Variables	Description	Source of volume estimates
I1	Water from Km4 pump station	est. from electricity payment (10%)
I2	Water from Hongthong pump station	est. from electricity payment (10%)
I3	Wastewater (non-purification)	Urban Cleaning Project, VC
I4	Wastewater (purification)	Urban Cleaning Project, VC
I5	Rainfall	Weather Forecasting Center (10%)*
I6	Precipitation	Weather Forecasting Center
I7	Ground water return	est. 20 % of water used in irrigation

Water Outflow

Variables	Description	Source of volume estimates
O1	Non Kor pump station	est. from electricity bill
O2	Mueng Noi pump station	est. from electricity bill
O3	Evaporation	MRC (2005)
O4	Infiltration	Vivathnakun (2000)
Q5	Private pumps and leakages	Residual variable

Notes:

(1) est. = estimated

(2) * = There were two steps to estimate the rainfall inflow into TLM. First, we used the data from the Weather Forecasting Center (WFC) to estimate the total rainfall in VC in mil. m^3. Then we used the expert's judgment of 10% to estimate how much of that rainfall flowed into TLM.

2.3.3 Estimation results

In order to estimate the water balance model for TLM, we used various sources of data and experts' judgment. The results are shown in Table 6. December had the highest water level (0.81m) with about 1 million m^3 of water stock. But the month of April had the lowest water level (0.21 m) with only about 0.30 million m^3 of water stock.

Table 6. The results of the water balance estimation for TLM (2007)

Month	Water Stock (mil. m3)	Water level (m)
December	1.31	0.81
January	0.86	0.53
February	0.68	0.42
March	0.61	0.38
April	0.34	0.21

Source: the author's estimation in consultation with irrigation expert from VC's irrigation division

2.4 Aquatic Wetland Resources (AWR) – Species and Threats

2.4.1 AWR species in TLM

As mentioned in the previous section, the social and physical environment of TLM has been subject to drastic changes in the last two decades. According to the PRA, in 1975, the TLM was two to three times bigger than it is today (2006) and the water level was also much higher. The TLM was covered mostly by floating and land forests. There was a variety of animal species, including at least one large type of venomous snake, crocodiles, turtles and otters. The amount and species of fish and birds were more compared to the present day. However, the existing fish, bird and animal species have not been recorded. Due in part to government development projects, the abundant aquatic wetland resources of the TLM has declined sharply in recent decades. According to the PRA, many species are virtually extinct in TLM such as crocodiles (including the Siamese crocodile), herons, otters, white belly rats, and big snakes.

Today, from AWR perspective, TLM is still very important for fish, birds and vegetation. According to LARReC, there are about 21 fish species living in TLM (Appendix 4); 11 black fish[5] species (52.31%), 7 white fish[6] species (33.33%), and 3 exotic fish species (14.36%). There are also many species of non-fish animals such as frogs, toads, snails, June beetles, freshwater shrimps, crabs and other crustaceans[7]. There are about 41 types of vegetation[8] in TLM which are very important for its residents as sources of food and income.

2.4.2 Threats to AWR in TLM

In view of the fact that TLM is located near VC, which has high economic and population growth and that laws and enforcement are inadequate in conserving its AWR, the marsh is threatened by various factors such as wastewater, solid waste, land conversion, and irrigation.

Fish and other AWR depend on (dissolved) oxygen in the water to live. Wastewater from VC is a food source for water-borne bacteria. Bacteria decompose these organic materials using dissolved oxygen, thus reducing the dissolved oxygen available for fish and other AWR. The Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions. On the other hand, Chemical Oxygen Demand (COD) does not differentiate between biologically available and inert organic matter

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[5] Black fish are either non-migratory or only display short-distance migration, mostly lateral onto floodplains. Black fish are adapted to living in floodplain refuges and are better able to survive the harsh environments with low oxygen levels.

[6] White fish is fish species that display extensive, often long-distance longitudinal migrations that are normally followed by a lateral migration component. White fish often seek refuge in the main river channel in deep pool areas.

[7] In our study, we focused on frogs, crustaceans, and snails which are the most important non-fish animals for livelihood in TLM.

[8] In our study, we focused on only eight species which were critical to livelihood (as shown in Appendix 5).

and is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. Therefore, if the BOD level in the marsh is high, this means that bacterial growth will consume high levels of the oxygen in the marsh. The oxygen may diminish to levels that are lethal for most fish and other AWR. The same applies when the COD level is high.

Due to the lack of wastewater treatment systems, the wastewater from households, shops, and restaurants flows directly to TLM. The BOD and COD levels in the marsh have increased sharply compared to 1992. There are indications that the situation is getting worse (see Appendix 6).

Solid waste from households is the most serious threat to TLM. Due to the economic and population growth in VC, the amount of solid waste has increased. However, the capacity of VC's main solid waste collecting company, Urban Cleaning Service (UCS), cannot keep up with the high volume. According to government statistics, about 300 tonnes of solid waste were generated per day in VC in 2003, but only 150 tonnes were collected and disposed of by UCS. This means that half the amount of solid waste was illegally disposed of in swamps, rivers, and open land. TLM has become a major illegal dumping site for waste.

Because of the high demand for land coupled with a lack of protective laws and poor regulation enforcement mechanisms (Liemphrachanch 2005), there has been mass conversion of land. Houses, factories and shops have sprung up all over the area. This has had a direct negative impact on the ecosystem and AWR of the marsh.

The development of irrigation systems is another factor contributing towards the decline of AWR in TLM. Until the 1970s, TLM was covered mainly by land and floating forests. In order to promote rice self-sufficiency in the 1980s, the forests in TLM were cleared and transformed to rice fields. The decrease in water and forests has resulted in a corresponding decline in the number and species of fish and non-fish animals in the marsh. The effects of irrigation are further discussed in the next section.

The villagers' perceptions of the causes for the decline in fish numbers in TLM is shown in Table 7. The main causes cited were the lack of regulations to control fishing (56%), population increase (52%), decrease in water level in TLM (27%), and decrease of trees, grass and vegetation (27%). It shows that over-fishing, due to lack of regulatory control, was perceived as the most important reason.

Table 7. Villagers' perceptions of the causes for the decrease in the amount of fish in TLM

No.	Villagers' Reasons	Frequency	%
1	Decrease in water level in TLM	85	27
2	Decrease of trees, grass and vegetation	85	27
3	Increase in population	165	52
4	No rules and regulations for fishing	178	56
5	Others (wastewater)	61	19
	Total Respondents	317	

Source: household survey; multiple responses

2.5 Irrigation and Farming Issues in TLM

In order to promote agriculture and improve the livelihood conditions of villagers, two irrigation pumps stations were built in TLM – the Non Kor pump station in 1985 and the Mueng Noi pump station in 2002. Collectively, they have the capacity to irrigate over 300 ha (Table 8). Mueng Noi pump station provides irrigation water for three villages; Non Vai, Mueng Noi and Xieng Da. It should have a total irrigation water capacity of 200 ha but in reality, it provides only 75 % of its capacity. The Non Kor pump station provides irrigation water for two villages; Houa Khoua and Non Khor Neua. It has a total irrigation water capacity of 115 ha, but it provides only 61.7% of this due to lack of water during the dry season.

Table 8. The pump stations at TLM (2007)

No.	**Name of pump station**	**No. of pumps**	**Name of villages serviced**	**Expected Capacity (ha)**	**Actual capacity**	
					(ha)	**(%)**
1	Mueng Noi	No.1: 50 HP No.2: 25 HP No.3: 100 HP	(1) Non Vai (2) Mueng Noi (3) Xieng Da	200	150	75
2	Non Kor	No.1: 300 HP No.2: 100 HP	(1) Houa Khoua (2) Non Khor Neua	115	71	61.7

Source: IDVC (part of survey, 2007)
Note: HP = horsepower

Pump-based irrigation is used mainly during the dry season by diverting the water from the marsh to the irrigation canals. In reality, only 200 ha of rice farms in a dry season are irrigated. This is because of various reasons which are shown in Table 9 such as the lack of water supply (21%), the main irrigation canal being too shallow (34%), unequal water distribution (18%), and the high cost of irrigation water (4%). It is obvious that the last reason is not an issue for farmers in TLM.

Table 9. Villagers' perceptions of irrigation problems in TLM

No.	**Reasons**	**Frequency**	**%**
1	Lack of water supply	43	21
2	Main canal too shallow	70	34
3	Unequal water distribution	36	18
4	Wastewater from city	27	13
5	Lack of small canals	13	6
6	Expensive irrigation water	8	4

7	Health risks from wastewater	13	6
Total Respondents		205*	

Source: household survey
Note: * 205 farming households used irrigation during the dry season; multiple responses.

The households which use irrigation in TLM have formed two Water Using Groups (WUGs). Each WUG has the responsibility of managing the irrigation system, ensuring proper and equal water allocation for all the members, and collecting payment for the irrigation water. A committee sets a fixed timetable for water distribution.

Any household using irrigation water during the dry season has to pay a water fee of 30,000 kip per rai[9] (US$ 18.75/ha) to cover the irrigation fees[10] (electricity fees). However, due to technical problems with the pump irrigation systems, water shortages, and poor management, more than 40% of the farmers are dissatisfied with irrigation water levels and water distribution (Table 10).

Table 10. Farmers' satisfaction with irrigation services

No.	Items	Satisfied (%)	Neutral (%)	Dissatisfied (%)	Total (%)
1	Time of turning on pump	41.36	23.56	35.08	100.00
2	Irrigation water level	35.11	19.15	45.74	100.00
3	Price of irrigation water	42.78	40.11	17.11	100.00
4	Unequal water distribution	37.63	22.04	40.33	100.00

Source: household survey

Note: sample size = 205 households

Only about 36% of farmers have been given training by the government in using irrigation in rice production. This indicates that government agencies provide only small training opportunities for farmers to improve their knowledge on irrigation and rice production techniques.

2.6 National Legal and Institutional Framework Relating to Wetlands

2.6.1 National regulatory framework

AWR are important elements in the livelihoods of the Lao people, especially the poor. In considering the environmental and natural resource management issues that

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[9] US$ 1 = 10,000 kips; 1 rai = 0.16 ha

[10] Irrigation water debt is a big problem. According to the leaders of the two WUGs, it was very difficult to collect irrigation water fees from farmers. As the main canal was too shallow and there was a lack of small canals, farms located far from the main canal did not get enough water so the farmers refused to pay the irrigation fee (30,000 kip per rai or US$ 18.75 per ha of rice field). As a result, the WUG leaders have been unable to collect enough money to pay for the electricity charges and both WUGs are in debt to the Lao Electricity Company. However, as agriculture is a priority sector, the government has been paying the 'debt' of these farmers.

impact all economic sectors, the Lao government has undertaken some important policy and institutional measures to boost its capacity to manage its natural resources in a sustainable manner.

Several laws concerning natural resource and environmental issues have been passed in recent years. However, effective law enforcement has been hampered to a large extent by the absence of regulations and frameworks for such enforcement (Liemphrachanch 2005).

The main provision on wetlands is stipulated in the Land Law of 1997, which was amended in October, 2003. A wetland is defined in Article 23 as land which is under water or land in close proximity with water sources such as; underwater land, river banks, land formerly covered by water which has since dried up or land formed by a change or diversion of a waterway. Unfortunately, in Laos, there is no specific law or regulation on wetlands for their protection and management.

In practice, no land survey, measurement, or allotment of wetlands at local, regional or national levels have been undertaken. No national master plan for land has been put in place. Therefore, many rice-growing lands and marshes, particularly in areas surrounded by the big cities and towns like VC, have made way for residential buildings, shopping malls, factories, etc., which decrease the direct and indirect economic values of the wetlands (Liemphrachanch 2005).

2.6.2 Institutional framework

In Laos, there are many ministries and agencies involved in environmental management and conservation, including the Ministry of Agriculture and Forestry (MOAF), Science, Technology and Environment Agency (STEA), National Environment Committee (NEC), and Water Resources Coordination Committee (WRCC). However, none of these have a formal framework for the coordinated management of wetlands in Laos. The responsibilities and interests of the government agencies involved in wetland management are different between agencies. Therefore, there exists some conflicts between them in terms of managing wetlands plus their mandates are to various extents, overlapping, unclear, and unrealized (Liemphrachanch 2005).

3.0 PROFITABILITY OF RICE FARMING IN TLM

3.1 Profitability of Rice Farming

3.1.1 The costs of rice production

There are 7,731 households around TLM with 13 % of them being farming households. (Appendix 7). Only 30% of the total rice-growing area (1,434 ha) is used during the rainy season due to floods, and only 54% of the total rice-growing area is used during the dry season. There are 17 villages growing rice around TLM. The crop area of each village for rice is shown in Appendix 8.

Table 11. Costs and benefits of rice production

(US$/ha)

Costs, Revenues and Benefits	**Rainy season**	**Dry season**
Irrigation cost	**0.00**	**26.70**
Irrigation fee	*0.00*	*26.70*
Material input costs	**86.43**	**86.05**
Seeds	*26.66*	*29.44*
Fertilizers	*47.84*	*49.39*
Pesticides	*11.93*	*7.22*
Labor cost	**87.34**	**88.48**
Labor	*87.34*	*88.48*
Capital costs	**164.68**	**208.24**
Machines	*54.08*	*55.19*
Land	*79.80*	*123.26*
Transportation	*30.80*	*29.79*
(1) Total Costs	**338.45**	**409.47**
(2) Total Revenue	**536.31**	**590.96**
Yield (kg)	*3575.40*	*4924.69*
Price per kg	*0.15*	*0.12*
Net Benefits (2) – (1)	**197.86**	**181.49**

Source: field survey by author in 2007

Note: The exchange rate used here: US$ 1 = 10,000 kip

The costs of rice production were estimated from the household survey data. They were divided into four categories: irrigation cost; material input cost (seeds, fertilizers, and pesticides); labor cost; and capital cost (machines, land, and transportation).

Here, the irrigation cost refers to the irrigation water fees collected by the WUGs to pay for the electricity bill. The wages of non-family workers were counted as the labor cost, but we omitted the labor of family members in rice production. Meanwhile, the land cost was the cost of leasing the farmlands (by farmers who did not own the land). We did not include the opportunity cost of land for those who owned their land.

The average rice production cost in the rainy season was US$ 338.45 per ha and US$ 409.47 per ha in the dry season (Table 11). The difference in the costs of rice production between the two seasons was due to the difference in irrigation costs, labor costs, land costs, and pesticide costs. Farmers do not use irrigation during the rainy season. In the dry season, however, farmers have to pay an irrigation fee of US$ 26.70 per ha. Labor and land costs during the dry season were also higher than in the rainy season[11]. However, the cost of pesticides in the dry season was lower than in the rainy season.

3.1.2 Net benefits from rice production

In order to estimate the net benefits of rice production in TLM, we first had to estimate the cost of rice production as shown in the above sub-section. Then we estimated the average rice yield from the household survey data. Next, we calculated the average net benefits of rice production from the cost and output (yield) estimates. Finally, we estimated the total rice-growing area in dry and rainy seasons from key village informants (Appendix 9). The equations for the estimation of net rice production in TLM are as follows:

$$BR_{DS} = FA_{DS} \times b_{DS} \qquad \text{(Equation 5)}$$

$$b_{DS} = \frac{\sum_{h=1}^{n}[(y_{DS} \times p_{DS}) - (Cost_{DS})]}{n} \qquad \text{(Equation 6)}$$

$$Cost = Irrigation + Material + Labor + capital \qquad \text{(Equation 7)}$$

where,

BR_{DS} : Total net benefit from rice cultivation (kip)

FA_{DS} : Total farm area (ha)

b_{DS} : Average net benefit from rice production per household (kip/ha)

y_{DS} : Rice yield (kg/ha)

p_{DS} : Price of rice (kip/kg)

$Cost_{DS}$: Cost of rice cultivation (kip)

n : Number of sampled households

The average rice yield was 3,575 kg/ha, and 4,924 kg/ha during the rainy and dry seasons respectively. This indicated that dry season rice cultivation had a higher yield than the rainy season. However, the cost of rice production in the dry season was higher than that of rainy season as mentioned above. The total cultivated rice-growing

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[11] The labor cost refers to wages paid to non-family members. During the dry season, the demand for labor for construction work is higher than in the rainy season, so wages for rice production are higher during the dry season. The land cost was the cost of leasing land for farming while the opportunity cost of land was ignored. Some farmers have to pay high fees to lease land during the dry season, but during the rainy season, it is quite cheap.

area in the dry season was 589.4 ha, and 436.3 ha[12] in the rainy season (Appendix 8). Therefore, the total annual net benefit from rice production was about US$ 106,976 and US$ 86,344 during the dry and rainy seasons respectively (Table 12).

Table 12. Net income from rice production

	Rainy season	**Dry season**
Total rice area (ha)	436.3	589.4
Net benefit per ha(US$)	197.9	181.5
Total net benefit (US$)	86,344	106,976

Sources: field survey by author in 2007, village statistics and interviews with key informants

3.2 Benefits from Aquatic Wetland Resources (AWR)

3.2.1 Fish and non-fish AWR

There are various values one can glean from AWR; however, in this study, we focused on the direct use value of AWR in TLM. The direct use value of AWR refers to fish and non-fish animals[13], and vegetation[14]. In order to estimate the net benefit from AWR in TLM, first we estimated the cost of AWR, followed by the output of AWR from the household survey data. Then we calculated the average net benefit per household based on the cost[15] and production of AWR. Lastly, we estimated the total number of households collecting AWR in each village from key village informants (Appendix 9). The equations for estimating benefit from AWR are as follows:

$$BF_{DS} = Fhh_{DS} \times f_{DS} \qquad \text{(Equation 8)}$$

$$f_{DS} = \frac{\sum_{h=1}^{n} [(kgf \times fp) - (opc + tfc)]}{n} \qquad \text{(Equation 9)}$$

where,

BF_{DS} : Total net benefit from catching fish (kip)

Fhh_{DS} : Total number of household catching fish (kip)

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[12] The net benefit from rice production was not based on the total rice-growing area, because not all of it was used for rice cultivation. The area used was only 54% during the dry season and 30% in the rainy season.

[13] The non-fish animals refer to snails and frogs which are the main sources of income for the villagers in TLM.

[14] Vegetation refers to natural vegetation in the TLM. The main vegetables are morning glory and *kangchong*.

[15] There are two costs for catching fish; the opportunity cost of the time spent on fishing, and the cost of fishing tools. The estimation of the opportunity cost for catching fish and non-fish animals was based on the minimum wage of US$ 2.5 per day (8 hours) (information obtained from the PRA). The cost of fishing tools was calculated mainly from information from household survey questionnaire.

f_{DS} : Net benefit of fishery per household (kip)

kgf : Amount of fish per household (kg)

fp : Fish price (kip)

opc : Opportunity cost of the time spent fishing

tfc : Fishing tools cost (kip)

n : Number of sampled households

$$BV_{DS} = Vhh_{DS} \times v_{DS} \qquad \text{(Equation 10)}$$

$$v_{DS} = \frac{\sum_{h=1}^{n}[(kgv \times vp) - (opc)]}{n} \qquad \text{(Equation 11)}$$

where,

BV_{DS} : Total net benefit from vegetation collection (kip)

Vhh_{DS} : Number of vegetation-collecting households

v_{DS} : Average net benefit from vegetation collection per household (kip)

kgv : Amount of vegetation per household (kg)

vp : Vegetable price (kip/kg)

opc : Opportunity cost of vegetation collection (kip)

n : Number of sampled households

In the 17 villages, 23% (1,786) of the households caught fish during the rainy season, and 14% (1,113) during the dry season. About 31% (2,371) caught non-fish animals during the rainy season and 3% (236) during the dry season. According to key informants in the villages, the villagers caught non-fish animals while fishing. Therefore, the number of households catching fish and non-fish animals was the same as the number of households catching fish. In the dry season, this was 17.5% (1,349) of the households and in the rainy season, it was 53.8% (4,157). Meanwhile, 14% (1,131) collected vegetation during the rainy season and 9% (698) during the dry season (Appendix 9).

During the rainy season, the average net benefit from catching fish and non-fish animals per household was US$ 241.05, and US$ 60.76 during the dry season. The total value of catching fish and non-fish animals per households in the rainy season was

US$ 1,002,045 and US$ 81,965 in the dry season (Table 13).

In addition, the villagers also owned natural and man-made ponds. The total pond area was 68 ha. The average annual yield of fish from ponds was about 3,745 kg/ha (Gerrard 2004). This study found that the total net benefit[16] from aquaculture (fish) from ponds in the dry season was about US$ 381,990 (Table 14).

Table 13. Total annual net benefit from catching fish and non-fish animals

Net Benefit	**Rainy season**	**Dry season**
Number of households (hh)	4,157	1,349
Average net benefit (US$/hh)	241.05	60.76
Total net benefits (US$)	1,002,045	81,965

Sources: field survey by author in 2007, village statistics and interviews with key informants

Table 14. Total value of fish caught from ponds

Pond area and yield	**Value**
Total Area (ha)	68
Yield (kg/ha / year)	3,745
Total produced (kg)	254,660
Average price (kip/kg)	15,000
Total value in kip	3,819,900,000
In US$	381,990

Sources: Gerrard (2004) and PRA

Note: The exchange rate used was 1 US$ = 10,000 kip

3.2.2 Aquatic vegetation

There are 1,131 households that collect vegetation during the rainy season and 698 households during the dry season (Appendix 8). To estimate the total net benefit from vegetation collection in TLM, we first estimated the average net benefit from collecting vegetation per household from the household survey data[17]. Second, we

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[16] As it was difficult to estimate the cost of making the ponds and the opportunity cost of catching fish (from the ponds), we ignored the cost of aquaculture in our calculations.

[17] The cost of materials for collecting vegetables in TLM was low, so we neglected this. As for the

estimated the number of households that collected vegetation in TLM from key village informants. Equations 10 and 11 were used in the estimation of total net benefits from collecting vegetation.

During the rainy season, the average annual income (net benefit) from collecting aquatic vegetation per household was US$ 111.80 and it was US$ 50.02 in the dry season. The total income from aquatic vegetable collection was US$ 126,446 in the rainy season and US$ 34,914 in the dry season (Table 15).

Table 15. Total net benefit from vegetation collection

	Rainy season	**Dry season**
Vegetation		
Number of households (hh)	1,131	698
Average net benefit (US$/hh)	111.80	50.02
Total net benefit (US$)	126,446	34,914

Sources: field survey by author in 2007, village statistics and interviews with key informants

The net benefits from rice cultivation, catching fish and non-fish animals, and collecting vegetation per household unit were estimated as described above – the summary is shown in Table 16. In the rainy season, the highest net benefit per household came from catching fish and non-fish animals (241.05 US$/hh) followed by rice cultivation (184.82 US$/hh) and collecting vegetation (111.80 US$/hh). On the other hand, for the dry season, the net benefit from rice cultivation was the highest (186.14 US$/hh) followed by catching fish and non-fish animals (60.76 US$/hh), and vegetation collection (50.02 US$/hh). This indicates that the main source of income for the sampled households was fish during the rainy season and rice cultivation during the dry season.

Table 16. Net benefits per household

Activity	**Rainy season (US$/hh)**	**Dry season (US$/hh)**
Rice	184.82	186.14
Fish and non-fish	241.05	60.76
Vegetation	111.80	50.02

Source: survey calculations

3.3 Direct Net Benefits from TLM

In order to see the importance of TLM for local people living in the area, it is important to measure the total net benefits from rice cultivation, catching fish and non-fish animals, and collecting vegetation in the marsh. The direct benefit estimations have been covered in previous sub-sections.

The total direct net benefits from TLM are shown in Table 17. During the rainy season, AWR were found to be the most important source of income for the local

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opportunity cost of collecting vegetables, we considered this as equivalent to the opportunity cost of rice cultivation and catching fish.

people living around TLM with a share of 92.89% (rice cultivation provides the remaining 7.11%). Of this, fish and non-fish animals made up about 82.48% followed by vegetation collection (10.41%). In the dry season, AWR also played an important role for the local people providing 81.95% of the total income. The remaining 18.05% came from rice cultivation Out of the 81.95%, 64.46% came from aquaculture.

Table 17. Total direct net benefits from TLM

Source of income	**Rainy season**		**Dry season**		**Total**	
	1000 US $	**%**	**1000 US $**	**%**	**1000 US $**	**%**
Irrigation						
Rice cultivation	86.33	7.11	106.98	18.05	193.30	10.70
AWR						
Fish and non-fish	1,002.04	82.48	68.7	11.60	1,071	59.24
Aquaculture	-		382.0	64.46	382	21.13
Vegetation	126.45	10.41	34.9	5.89	161	8.93
Sub-total	1,128.49	92.89	485.6	81.95	1,614	89.30
TOTAL	1,214.82	**100.00**	592.6	**100.00**	1,807	**100.00**

Sources: field survey by author in 2007, village statistics and interviews with key informants

In sum, this study found AWR to be the most important source of income in the TLM, with a share of 89.3%. Within this, catching fish and non-fish animals accounted for 59.24%, aquaculture for 21.13%, rice cultivation for 10.7%, and vegetation collection for 8.93%. This result indicates that AWR are more critical than rice cultivation to the livelihoods of the TLM communities.

3.4 Comparison between the Net Benefits from Rice Production and AWR in TLM

3.4.1 Net benefits by activity per land area

In order to determine the efficiency of land use in TLM, the net benefits from rice cultivation, catching fish and non-fish animals, and collecting vegetation per land area (in ha) were estimated. We estimated the land area used for each activity (rice cultivation, catching fish and non-fish, and collecting vegetation) from the total land area shown in Figure 2. As mentioned earlier, official data on land area is not available in Laos. In order to have the land area in TLM for purposes of this study, we asked the National Geographic Department under the Prime Minister's Office to provide us with estimates[18].

The estimated land area by activity in TLM is shown in Table 18. The rice cultivation area in the rainy season was 436.3 ha and in the dry season, it was 589.4 ha (Table 12). We assumed that the land area for fish and non-fish catching as equivalent to the land area under water. In the rainy season, this figure was 1,631.41 ha, estimated from total area minus the road, settlement, and factory areas. According to our key

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[18] The estimation of the land area in TLM was based on the Vientiane city map of 1999 which was updated in 2006.

informants, there were not many fish and non-fish animals living in the rice fields in the dry season due to the use of pesticides by farmers[19], so most of the fish and non-fish catch was from swamps, ponds, and canals, which collectively covered 162.91 ha. The land area for vegetation collection in the dry season was 196.45 ha, representing the total area under swamps, ponds, canals, rice fields, and grass.

Table 18. Land area in TLM by activity

Activity	Rainy season (ha)	Dry season (ha)	Land area for the various activities in the dry season
Rice cultivation	436.3	589.4	Rice fields
Fish and non-fish	1631.41 *	162.91	Swamps + ponds +canals
Aquaculture	-	68.00	Ponds
Vegetation	1631.41 *	196.45	Swamps + ponds + canals + rice fields + grass

Note: *The area for fish, non-fish and vegetation in the rainy season was estimated from the total area minus the area under roads, settlements and factories.

Next, we estimated the total net benefit from each activity, using the figures given in the previous sub-sections. The results of the estimation are shown in Table 19. For the dry season, the highest net benefit per land area came from aquaculture (5,617 US$/ha) followed by fish and non-fish catch (503.13 US$/ha), rice cultivation (181 US$/ha) and vegetation (177.72 US$/ha). This indicates that in terms of land area used, AWR bring in more benefits than rice cultivation.

Table 19. Net benefits from activities per land area

Activity	Rainy season (US$/ha)	Dry season (US$/ha)
Rice cultivation	197.86	181.49
Fish and non-fish	614.22	503.13
Aquaculture	-	5617.50
Vegetation	77.51	177.72

Source: survey calculations

3.4.2 Net benefits by activity per volume of water used

We estimated the net benefits by activity per volume of water used in order to determine the demand for water in TLM[20]. First, we estimated the amount of water used for each activity based on the water balance model described in Section 2 (see Table 20 for the summary). We assumed that the water used for rice cultivation during

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[19] If the external cost of pesticides is taken into account, then the benefits from irrigation would be further reduced.

[20] We focused on net benefits by activity per volume of water used during the dry season because the impact of irrigation on AWR occurs during the dry season.

the dry season was the total volume of irrigation water minus the volume of water which flowed back to TLM. We also assumed that the volume of water for fish and non-fish life, aquaculture, and vegetation as the average volume of water in TLM from December to March (the dry season).

Table 20. The volume of water used per activity

Activity	**Volume of water (mil. m^3)**	**Remarks**
Rice cultivation	2.12	Total volume of irrigated water - volume of water that returns back to the TLM
Fish and non-fish	0.76	Average volume of water in TLM from Dec to Mar
Aquaculture	0.76	Average volume of water in TLM from Dec to Mar
Vegetation	0.76	Average volume of water in TLM from Dec to Mar

Source: estimated from the water balance model

Using the above volume estimates and total net benefits of each activity estimated in previous sub-sections, we calculated the net benefits by activity per cubic meter of water (Table 21). Aquaculture ranked the highest at 0.50 US$/$m^3$, followed by fish and non-fish catching (0.09 US$/ m^3), rice cultivation (0.05 US$/ m^3), and vegetation collection (0.02 US$/ m^3). This indicates that the net benefits from AWR per volume of water used are higher than from rice cultivation in TLM during the dry season.

Table 21. Net benefit by activity per cubic meter of water used

Activity	**Dry season (US$/$m^3$)**
Rice cultivation	0.05
Fish and non-fish	0.09
Aquaculture	0.50
Vegetation	0.02

Source: author's calculations

4.0 THE DEMAND FOR IRRIGATION WATER AND FACTORS AFFECTING RICE PRODUCTION

4.1 The Demand for Irrigation Water in TLM

It is important to assess the demand for irrigation water in TLM in order to analyze how to reduce the volume used and increase the water supply for the AWR in the marsh. In order to assess the demand for irrigation water in TLM, it is important to have a standard water usage requirement for rice production and compare this to the actual volume of water used in the marsh.

The standard water usage requirement for rice cultivation during the dry season was estimated by the Ministry of Agriculture and Forestry (MOAF) in 2001. The equation is as follows:

$$CWR = (NR*10{,}000)/1{,}000 \qquad \text{(Equation 12)}$$

where,

CWR: Water requirement for rice production during the dry season in VC (m^3/ha)

NR: Net water requirement for rice production (mm)

where,

$$NR = CU + P - ER + PW \qquad \text{(Equation 13)}$$

where,

NR: Net water requirement for rice production (mm)

CU: Water consumption (mm)

P: Percolation[21] (mm/day)

ER: Effective rainfall (mm)

PW: Puddling water requirement (mm)

According to the MOAF (2001), the net water requirement for rice production during the dry season (NR) was 1,079 mm and using Equation 12, the standard water requirement for rice production during the dry season in VC was 10,790 m^3/ha.

The actual volume of irrigation water used per hectare (m^3/ha) was calculated from the total volume of water used by the two irrigation pump stations divided by the total irrigated area during the dry season. The total volume of water used for irrigation during the dry season was 2.12 million m^3 (Table 20) for 589.4 ha of rice land (Table 18). Therefore, the actual quantity of water used for rice cultivation was 3,597 m^3/ha.

In comparing the standard or optimum water usage requirement (10,790 m3/ha) with the actual amount of water used for rice cultivation during the dry season (3,597m^3/ha), it can be seen that the latter is lower than the former by about 66.67 %, indicating that there is an acute shortage of irrigation water in TLM. Therefore, the demand for irrigation water is very high in TLM.

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[21] Under flood conditions, water is required to match several outflow processes. Because of the standing water, hydrostatic pressure continuously "pushes" water downward through the puddled layer. When this water flows vertically downward below the root zone, it is called "percolation" (Bouman, 2002).

Table 22. A comparison between the standard water usage requirement and the actual usage of irrigation water in TLM

Water usage for rice cultivation during the dry season	**m^3/ha**
Standard water usage requirement for rice cultivation*	10,790
Actual water used for rice cultivation**	3,597
Difference (%)	66.67

Notes:
(1) * = standard value from MOAF (2001)
(2) ** = from the author's calculations.

4.2 Rice Production Functions

4.2.1 Models

In order to evaluate the impacts of various factors including socio-economic characteristics and training in rice production, the production function models were based on the model developed by Kompas (2002). The rice production function was a Cobb-Douglas function. The basic form of the model used is as follows:

$$Y= e^{\Sigma\alpha\ i^{Di}}\ LA\alpha^{1}\ LB\alpha^{2}\ KM\alpha^{3}\ KM\alpha^{3} IR\alpha^{4} EDU\alpha^{5} AGE\alpha^{6} \qquad \text{(Equation 14)}$$

where,

Y: Output of rice production (tonnes)

LA: Land area inputs (ha)

LB: Labor inputs (person)

KM: Capital inputs (kip)

IR: Volume of irrigation water (cubic meters)

Di: Dummy variables (socio-economic characteristics, and training experiences), i = 7, 8, 9.

Using a general log-linear specification in the above model, the function form was changed to the following:

$$Ln(Y)= \Sigma\alpha iDi + \alpha 1Ln\ (LA)+ \alpha 2Ln(LB)+ \alpha 3Ln(KM) + \alpha 4\ Ln(IR) + \alpha 5\ Ln(EDU) + \alpha 6\ Ln(AGE) \qquad \text{(Equation 15)}$$

The definitions of the variables are given in Table 23. Based on this model, we could identify the factors affecting rice production during the dry season.

Table 23. Definitions of variables in the rice production functions

Variables	Definition	Unit	Expected sign
Y	Output of rice	tonnes per year	NA
LA	Land area	ha	+
KM	Capital	kip	+
LB	Labour	person	+
IR	Volume of irrigation water	cubic meter	+
AGE	Age	year	+
SEX	Gender	male=1, other=0	+
EDU	Education	number of years in school	+
IRTRA	Training in irrigation water use	trained = 1, other = 0	+
RITRA	Training in producing rice	trained = 1, other = 0	+

The land area was the actual rice cultivation area. Labor were family members producing rice. The capital input included: machine costs for all stages of rice production, land lease costs for growing rice, transportation costs for rice production, wages for non-family members, costs of seeds used, irrigation water fees (only for dry season rice production), fertilizer costs, and pesticides costs. The volume of irrigation water is the average volume of irrigation water used in the dry season, estimated from the average height of irrigation water in the rice fields and the rice-growing acreage information obtained from the household survey. All four variables were expected to have positive signs and be significant in the model.

Households with male heads were described as those having experience and leadership ability in rice production[22]. Therefore, households with male heads were expected to have a positive impact on rice production. Education (EDU) referred to the level of technology used in rice production. A higher educated farmer was expected to have a positive impact on rice production. The age (AGE) of the household head was expected to have a statistically positive, significant relationship with rice yields. Training by government agencies in the use of irrigation water (IRTRA) and on producing rice (RITRA) were expected to be positively and significantly related to rice production.

The characteristics of the sampled households in the dry season rice production function are shown in Appendix 10. For the dry season rice production function, the average respondent was 51 years old, had six years of schooling, and produced 3.87 tonnes of rice per year. In terms of factors of production, the average input consisted of three persons for labor, 1.18 ha of land, 10 m^3 of irrigation water, and a capital investment of 1.68 million kip (US$ 168) (Appendix 10).

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[22] According to Lao tradition, men always take the lead in agricultural production, while females see to the housework. Therefore, households with male heads are expected to have higher rice yields than households with female heads.

4.2.2 Results

We used the two-stage OLS (Ordinary Least Square) method. In order to avoid multicollinearity in the independent variables, the correlation matrix method was employed. We chose variables which had correlations of less than 50%. The Breusch-Pagan test was used to check whether the model has any heterosdascticity or not (Wago and Ban 1995). We estimated two rice production functions in order to investigate the impact of various variables on rice production. The results are explained below.

Main Model

A model without socio-economic characteristic dummy variables is called the main model (Table 24). The adjusted R^2 of this model was 73 %, showing goodness of fit of the model. The Breusch-Pagan test indicated that there was no heterosdascticity. The land, capital and labor inputs were found to be statistically significant with expected signs, but the labor input was not statistically significant.

As expected, the volume of irrigation water used (IR) had a statistically significant impact on rice production. If other input variables such as capital and labor are constant, and if the volume of irrigation water increased by 1%, rice production would increase by 0.29 % (Table 24).

Model with socio-economic characteristics (Model 1)

The socio-economic characteristics of the respondent (age, gender and education) are important to rice production in the dry season. The farmer's knowledge on irrigation water usage and rice production also plays an essential role. Therefore, we added two training dummy variables (training on irrigation water usage and rice production) to the main model to create Model 1 (Table 24).

In Model 1, we found that only the gender variable had a statistically positive and significant impact on rice production. This means that if the head of the household was male rather than female, there would be a positive impact on rice production. This also implies that if the head of the household was a woman, rice production would not increase (because woman head of household was a dummy variable = 0). The dummy for training on irrigation water use was statistically positive and significant, but the training on rice production was not statistically significant (Table 24). This indicates that farmers who have received training in irrigation water usage would have higher rice outputs than those without such training.

Table 24. Rice production function (for the dry season)

Variable	Main Model		Model 1	
	Coefficient	t-statistic	Coefficient	t- statistic
C	-0.53	-0.98	-1.36**	-1.94
LN(LA)	0.24***	2.56	0.17**	1.86
LN(KM)	0.90***	2.26	0.08**	1.89
LN(LB)	0.07	1.17	0.02	0.44
LN(IR)	0.29***	7.80	0.31***	8.12
SEX			0.16**	2.71
LN(AGE)			0.100	1.00
LN(EDU)			0.110	1.41
IRTRA			0.14***	2.40
RITRA			-0.05	-0.76
Adjusted R^2	0.73		0.76	
F(zero slopes)	113.68***		59.92***	
Std. dev	0.72		0.70	
Observation	168		168	

Source: author's estimations

Note: *** denotes statistical significance at 1% level; ** denotes statistical significance at 5% level; * denotes statistical significance at 10% level.

5.0 IMPACT OF IRRIGATION AND A MINIMUM WATER LEVEL FOR AWR CONSERVATION IN TLM

5.1 Introduction

Water withdrawals from the marsh can have negative effects on its ecosystem particularly when it crosses certain thresholds. Therefore, water withdrawal for paddy irrigation should be in harmony with the ecological water requirements of TLM. It is thus important to measure the impact of irrigation on the AWR of TLM and consider setting a minimum water level requirement to conserve them.

In this section, we discuss the measurement of the impact of irrigation on AWR followed by our attempts to identify a minimum water level requirement in TLM and measure its impact on rice production and AWR.

5.2 The Impact of Irrigation on AWR

5.2.1 The current situation

The current situation refers to the situation discussed in Section 2. The average volume of TLM is about 0.76 million m^3, the water level height is 0.41 m, the total area under water is 196.45 ha (Table 25), and the total volume of water drained for irrigation is about 2.12 million m^3 during dry season.

5.2.2 Assumptions and conditions of the simulation scenario

In order to simulate the impact of irrigation on the AWR in TLM, we made the assumption that there was no use of water for irrigation from the marsh. Based on our calculations using the water balance model in Section 2, if the volume of water in the marsh increased by 69%, the marsh water level would increase by 33%. The increase of land area under water in TLM was based on the irrigation experts' estimation. The irrigation experts from IDVC responsible for developing irrigation projects in the TLM were brought to TLM several times to assess the increase in land area under water[23]. According to their judgment, the marsh, with its ponds, canals, and swamps, was deep. Therefore, if the volume of water increased by 69%, the area under water would increase by 4-5%. A summary of the simulation conditions is given in Table 25.

Table 25. Simulation conditions (no irrigation scenario)

Marsh conditions	Current situation	Simulation conditions	Remarks
The average volume of water in the marsh (mil. m^3)	0.76	69 % increase	Calculation from water balance model
The average level of water in the marsh (m)	0.41	33 % increase	Calculation from water balance model
Area of marsh under water (ha)	196.45	4-5 % increase	Experts' judgment

5.2.3 Simulation results

In order to estimate the impact of irrigation on the AWR of TLM, it would have been ideal to use a production function which incorporated the volume of water in the marsh, marsh water level, and land area under water. Unfortunately, we could not obtain the information for these coefficients to support this study. For this reason, in this study, the estimation of the impact of irrigation on AWR is based on the fishery experts' judgment.

Two fishery experts from LARReC were brought to TLM several times during both the dry and rainy seasons. Their judgment was based on the assumptions and conditions of the simulation scenario which were extracted from the water balance model in Section 2 (see Table 25) and the existing characteristics of fish and non-fish species living in TLM (see Appendix 4).

The simulation results of the impact of not removing water for irrigation on TLM's AWR are shown in Table 26. If the water in the marsh was not used for

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[23] According to the irrigation expert from DIVC, the increase of land area under water could be calculated from a geographic map by using specific software. However, due to limited time and resources, we used his judgment instead to predict the change of land area under water in TLM.

irrigation, the amount of AWR would rise due to the increase in the volume of water available, water level and land area under water. Fish and non-fish life, aquaculture, and vegetation would increase by 10-15%, worth US$ 6.87-8.59 thousand, US$ 38.20-47.75 thousand and US$ 1.55-2.23 thousand, respectively.

Table 26. Impact of ‘no irrigation’ on the AWR of TLM (simulation scenario)

AWR	**Current value (‘000 US$)**	**Impact of “no irrigation’ on AWR**	
		Increase (%)	**Value (‘000 US$)**
Fish and non-fish	68.70	10-15	6.87-8.59
Aquaculture	382.00	10-15	38.2-47.75
Vegetation	15.50	10-15	1.55-2.33
Total	**466.20**	**12.5***	**58.28***

Notes:

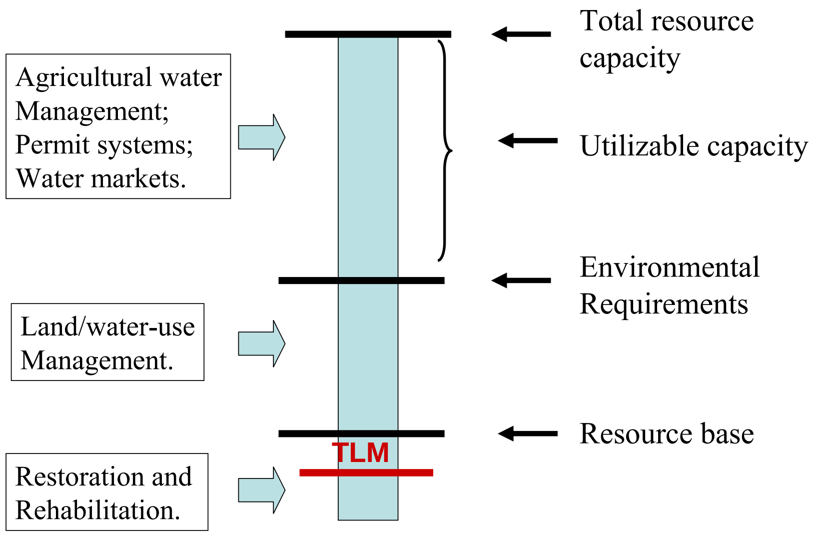
(1) *12.5% (and US$ 58.28 thousand) is the average increase of AWR if TLM water is not used for irrigation. The calculation was done in two steps. First, we calculated the average rates of increase of each AWR item. Then we calculated the average of these.
(2) The price used was the current market price in 2007.

The simulation results indicate that irrigation would cause the AWR to decrease by 12.5%, worth US$ 58.28 thousand per year. Although the impact in terms of percentage is small, it becomes large when converted to monetary value because as we have shown earlier, AWR contribute the most to the total income earned in TLM.

5.3 Minimum Water Level Requirement for AWR

5.3.1 The current situation

Balancing the trade-offs between food production and maintenance of freshwater ecosystems is already on the agenda of many countries of the world, particularly those with limited freshwater resources (Smakthin 2002). Smakthin (2002) states that there are water level thresholds relating to different levels of utilization of freshwater ecosystem resources and recommends a minimum water level requirement to be set in developing countries to maintain the resource base of their wetlands and rivers. The study was focused on TLM (see Figure 4).



Source: Samakhtin (2002), IWMI

Figure 4. Water level thresholds in TLM

The minimum water level requirement for AWR is different for different types of wetland ecosystems. In TLM, there are many kinds of wetland ecosystems. However, in this study, we focused on fish because it was an important consumption item and source of income for the local people of TLM.

5.3.2 Assumptions and conditions of the simulation scenario

In order to identify the minimum water level requirement for TLM and analyze its impact, we followed the steps below.

Step 1: Identify the minimum water level for AWR in TLM

There are very few studies on the setting and analysis of a minimum water level requirement for freshwater ecosystems. According to the fishery experts from LARReC, the minimum water level requirement for AWR in TLM should be 0.5 m, based on the characteristics of the fish species in TLM discussed in Section 2. Using this recommended minimum level requirement, the water level in TLM was seen to fall short in the months from February to April 2007. The readings were 0.42 m for February, 0.38 m for March and 0.21 in April, the lowest water level in TLM for that year (Table 6).

Step 2: Estimate the volume of irrigation water used and water stock at TLM

We estimated the changes in the volume of irrigation water used and water stock at TLM when the minimum water level requirement was set at 0.5 m, using the water balance model (see Section 2).

The results of the estimation are shown in Table 27. If the water level in the marsh is set at 0.5 m, the volume of irrigation water used would decrease by 70% (1.48 mil. m^3) and the volume of water in TLM would increase by 30% (0.23 mil. m^3).

Table 27. Simulation conditions (minimum water level at 0.5 m scenario)

Marsh and irrigation conditions	**Current situation**	**Simulation conditions**	**Remarks**
The average volume of water in the marsh (mil. m^3)	0.76	30.7% increase	Calculation from water balance model
The average volume of water for irrigation (mil.m^3)	2.12	70% decrease	Calculation from water balance model
The average marsh water level(m)	0.41	22% increase (from 0.41 m to 0.5 m)	Calculation from water balance model
Area of marsh under water (ha)	196.4	3-4% increase	Experts' judgment

Step 3: Estimate the revenues from AWR and the loss of revenues from irrigated rice farming

As mentioned in Step 2, if the minimum water level is set at 0.5 m, the quantity of irrigation water would reduce, but the volume of water in TLM would increase. The measurement of loss of revenues from rice production was based on the decrease in the amount of irrigation water used. We used the rice production function from the previous section[24] to estimate the loss of rice production resulting from the setting of a minimum water level requirement for TLM.

$$LN(Y)= -0.53+ 0.24\ LN(LA)+0.07\ LN(LB)+0.90\ LN(KM) +0.29\ LN(IR)$$

(Equation 16)

where,

Y: Output of rice production (tonnes)

LA: Land area inputs (ha)

LB: Labor inputs (person)

KM: Capital inputs (kip)

IR: Volume of irrigation water (cubic meters)

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[24] For more details, please see the main model results in Table 24.

In Equation 16, we assumed that other input variables (labor, land and capital) were constant. If irrigation water use decreased by 70%, rice production would reduce by 20.3 %, worth US$ 21.72 thousand[25].

Step 4: Estimate the percentage change in AWR

As we could not find any AWR function or coefficients in literature to estimate the benefits to AWR from the increased volume of water, water level and land area under water, we used the judgment of fishery experts to do this. Based on the increase in the water stock of TLM, the land area under water, and the characteristics of the fish species in the marsh, they estimated the percentage change in AWR in TLM (shown in Table 26).

5.3.3 Simulation results

The impact of setting a minimum water level of 0.5 m for TLM was estimated based on the assumptions and conditions of the simulation scenario as discussed above. The results are shown in Table 28. If the minimum water level requirement in TLM is set at 0.5 m during the dry season, the total rice output in TLM would decrease by 20.3 %, worth US$ 21.72 thousand. On the other hand, the revenue from AWR would increase by 10%, worth US$ 48.56 thousand. In comparing the loss from rice cultivation and the revenue gain from AWR, it is clear that the latter is much more than the former.

Table 28. The impact of setting a minimum water level requirement for TLM

Activity	**Current Value ('000 US$)**	**Impact on Minimum Water Level setting**	
		Change (%)	**Value ('000 US$)****
Rice cultivation*	106.98	20.30 (decrease)	21.72
AWR:			
- Fish and non-fish	68.70	6-12 (increase)	4.12-8.24
- Aquaculture	382.00	7-14 (increase)	26.74-53.48
- Vegetation	34.90	7-14 (increase)	2.44-4.89
Total	**485.60**	**10.0 (increase)**	**48.56**

Source: author's estimations

Notes:
(1) * We did not include the use of self-owned pumps (as it was a residual variable in the water balance model).
(2) ** The price was the current market price in 2007.

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[25] In Equation 16, the coefficient of LN(IR) is 0.29. If irrigation water is reduced by 70%, rice production would reduce by 20.3 % (0.29*70). The net value of rice cultivation during the dry season is US$ 107 thousand (Table 17). Therefore, rice production would reduce by US$ 21.72 thousand.

6.0 CONCLUSIONS AND POLICY RECOMMENDATIONS

6.1 Conclusions

This study attempted to identify the trade-offs between the benefits from irrigation and AWR in TLM. The total net benefit from AWR (82%) is substantially higher than the net benefit from irrigated rice production (18%) during the dry season. It indicates that AWR are more important than rice cultivation during the dry season for the local inhabitants of TLM.

The volume of water used for irrigation during the dry season was found to be higher than the standard water use requirement. It shows that there is a high demand for irrigation water in TLM and that a shortage of irrigation water will have serious impacts on AWR in the marsh.

Training on the use of irrigation water played an important role in dry season rice production. The irrigation water used in TLM had a negative impact on AWR; the average percentage loss of AWR was 13% worth for US$ 58.28 thousand during the dry season.

The water level in TLM in some months during the dry season was found to be below the minimum water level requirement for TLM as recommended by the experts used in this study. If this minimum water level requirement was set, the net benefit from AWR would increase by about 10%, worth US$ 48.56 thousand, but the total rice production in the marsh would decrease by 20.3%, worth US$ 21.72 thousand. It is clear that the revenue gain from AWR would be higher than the loss in rice production if this minimum water level were to be set.

In conclusion, irrigation drains water off TLM and decreases the water level in the marsh during the dry season, causing a negative impact on its AWR. Although irrigation water use in the dry season is already limited, it still exceeds the recommended minimum water level requirement for the marsh. Thus, setting a minimum water level requirement to restrict the use of irrigation water for rice cultivation during the dry season is necessary.

6.2 Policy Recommendations

Based on the results of this study, some recommendations for policy-makers in Laos are made.

Effective wetland management requires reliable statistics and information on wetland resources, land transformation, water use information, key threats and so on. However, the relevant government agencies in the country have overlooked this. They should pay more attention to collecting and analyzing such critical data before the implementation of any plans for the wetlands.

This study also found that there is a shortage of irrigation water in TLM and knowledge on the use of irrigation is poor. In order to improve this situation, more training on irrigation water use and alternative crops should be provided to the rice farmers of TLM. The main and small irrigation canals should also be improved and a more equitable distribution system of irrigation water, developed.

To date, there have been no clear water allocation rules and regulations for AWR conservation and rice cultivation in TLM. In order to maintain both, it is important to consider setting a minimum water level for TLM which will be the basic threshold to ensure the conservation of its precious AWR. This option would lead to a reduction in rice production during the dry season. However, this loss could be mitigated if the farmers could be trained on how to use irrigation water effectively, grow alternative crops that required less water than rice, catch fish and collect vegetables.

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APPENDICES

Appendix 1. Population of TLM

	Villages	**Total Households**	**Total population**	**Aged 0-14**	**Aged 15-19**	**Aged 20-60**	**Aged >60**
1	Donekoi	564	2654	784	330	1444	96
2	Dongkhamxang	390	2406	621	427	1285	73
3	Dongsavat	488	2736	728	363	1545	100
4	Hongkea	471	2557	644	275	1508	130
5	Houakhoua	327	2001	452	407	1052	90
6	Muengnoi	370	1848	509	240	995	104
7	Nahai	513	2401	705	279	1308	109
8	Nonghai	649	3427	1016	409	1859	143
9	Nonkhorneua	417	2250	658	251	1223	118
10	Nonvai	408	1948	602	229	1034	83
11	Phonpapao	682	5354	855	979	3346	174
12	PhonthanNeua	383	2145	552	255	1229	109
13	PhonthanTai	316	2143	439	257	1363	84
14	Salakham	279	1508	434	182	806	86
15	Somsanouk	551	2697	679	361	1562	95
16	Thatluang Tai	542	3260	824	412	1825	199
17	Xiengda	381	2165	654	286	1146	79
	Total	7731	43500	11156	5942	24530	1872
	%			25.65	13.66	56.39	4.30

Source: National Statistics Center

Appendix 2. Occupation sectors of TLM residents

No.	Villages	Rice cultivation	Garden cultivation	Government officer	Private sector workers	Workers at state-owned enterprises	Laborers	Unemployed
1	Donekoi	74	3	153	399	51	7	55
2	Dongkhamxang	98	54	117	249	13	6	37
3	Dongsavat	34	4	120	434	44	10	46
4	Hongkea	15	-	184	340	23	2	81
5	Houakhoua	45	3	71	493	24	10	32
6	Muengnoi	422	11	66	101	21	3	46
7	Nahai	300	17	66	455	74	6	60
8	Nonghai	117	38	167	787	67	16	87
9	Nonkhorneua	48	6	178	168	28	5	88
10	Nonvai	119	98	123	166	21	2	39
11	Phonpapao	76	2	276	2372	80	23	166
12	PhonthanNeua	70	4	61	176	16	10	41
13	PhonthanTai	17	5	197	243	30	3	80
14	Salakham	43	27	50	248	39	5	83
15	Somsanouk	25	3	86	783	34	62	80
16	Thatluang Tai	22	2	227	431	49	8	173
17	Xiengda	377	259	98	117	23	-	4
	Total	1902	536	2240	7962	637	178	1198
	% of total	12.98	3.66	15.29	54.34	4.35	1.21	8.18

Source: National Statistics Center
Note: The numbers refer to headcount

Appendix 3. Percentage of households who own title deeds to land in TLM

No.	Villages	Total no. of HHs*	HHs with land titles in TLM (%)	Year of receiving
1	Donekoi	564	40	2004
2	Dongkhamxang	390	0	-
3	Dongsavat	488	30	2002
4	Hongkea	471	50	2004
5	Houakhoua	327	30	2002
6	Muengnoi	370	60	2002
7	Nahai	513	50	2004
8	Nonghai	649	40	2004
9	Nonkhorneua	417	30	2002
10	Nonvai	408	40	2002
11	Phonpapao	682	40	2002
12	PhonthanNeua	383	20	2002
13	PhonthanTai	316	10	2002
14	Salakham	279	45	2004
15	Somsanouk	551	50	2005
16	Thatluang Tai	542	40	2004
17	Xiengda	381	70	2002
	Total	7731	37.94	

Sources: Interviews with village heads and PRA

Note: HH = households in the villages

Appendix 4. Fish species in TLM

No.	Lao name	Scientific name	Remarks
1	Pa Khor	Channa striata	Black fish
2	Pa Douk	Clarias macrocephalus	Black fish
3	Pa Douk	Clarias batrachus	Black fish
4	Pa Kheng	Anabas testudineus	Black fish
5	Pa Kadeut	Trichogaster trichopterus	Black fish
6	Pa Salit	Trichogasterpectoralis	Black fish
7	Pa Bou	Oxyeleotris marmorata	Black fish
8	Pa Ka	Pristolepis fasciata	Black fish
9	Pa Siew	Esomus metallicus	Black fish
10	Pa Siew	Esomus goddaroli	Black fish
11	Pa Mat	Trichopsis vittatus	Black fish
12	Pa Soud	Hampala macrolepidota	White fish
13	Pa Tong	Chitala ornata	White fish
14	Pa Seuam	Ompok bimaculatus	White fish
15	Pa Pak	Puntius gonionotus	White fish
16	Pa Pak	Puntius daruphani	White fish
17	Pa Khao Mon	Puntius brevis	White fish
18	Pa Kot	Mystus nemurus	White fish
19	Pa Nin	Tilapia nioticus	Exotic fish species
20	Pa Nai	Cyprinus carpio	Exotic fish species
21	Pa Kin Gna	Ctenopharyngodon idellus	Exotic fish species

Source: MRC 2003

Appendix 5. Vegetation species in TLM

No.	Local name	Scientific name	English name
1	Puk Bong	Ipomea aqautica	Morning glory
2	Nae	Hydrilla verticillata Presl. AqH	Water thyme
3	Puk Tob	Eichhornia crassipes	Water hyacinth
4	Puk Kan Jong	Limnocharis flava	Yellow sawah lettuce
5	Jok	Pistia stratiotes L.	Coontail, Tropical duckweed
6	Karn Tan	Alternanthera sessilis (L.)DC.	Alligator weed, Sessile joyweed
7	Yar Karb	Commelina diffusa Burn.f.	Spreading dayflower
8	Buao	Nelumbo nucifera Gaertn.	Lotus

Source: Samuelsson and Osterling (2006)

Appendix 6. Water quality monitoring at Ban Houakhoua (TLM)

Year	**Temp. (^0C)**	**PH**	**NO_3-N (mg/l)**	**NH_4-N (mg/l)**	**PO_4-P (mg/l)**	**Tot-P (mg/l)**	**BOD (mg/l)**	**COD (mg/l)**
1992	27.4	6.52	0.369	0.208	0.025	0.042	4.203	7.663
1998	26	6.7	0.408	0.344	0.051	0.088	32	76
2002	27	8.1	0.708	2.288	0.52	-	-	-
2005	27	8.13	0.171	6.203	0.261	0.599	-	-
Standard		6.5 - 8.5	5 - 15	0.3 - 0.5				

Sources: Phithayaphone (1992), LARReC (1999) and Lacoursiere (2005)

Note: PH: Acidity/Alkalinity; NO_3-N: Nitrate Nitrogen; NH_4-N: Ammonium Nitrogen; PO_4-P: Soluble-reactive P; Tot-P: Phosphorus; BOD: Biochemical Oxygen Demand; COD: Chemical Oxygen Demand

Appendix 7. Number of farming households in TLM

No.	**Villages**	**Total no. of households**	**Total no. of persons**	**Farming households**	
				Households	**%**
1	Donekoi	564	2654	80	14.3
2	Dongkhamxang	390	2406	69	17.7
3	Dongsavat	488	2736	27	5.5
4	Hongkea	471	2557	15	3.2
5	Houakhoua	327	2001	45	13.8
6	Muengnoi	370	1848	96	25.9
7	Nahai	513	2401	58	11.4
8	Nonghai	649	3427	19	3.0
9	Nonkhorneua	417	2250	244	58.5
10	Nonvai	408	1948	119	29.2
11	Phonpapao	682	5354	95	14.0
12	PhonthanNeua	383	2145	5	1.2
13	PhonthanTai	316	2143	26	8.2
14	Salakham	279	1508	7	2.4
15	Somsanouk	551	2697	17	3.1
16	Thatluang Tai	542	3260	28	5.1
17	Xiengda	381	2165	48	12.6
	Total	7731	43500	998	13.5

Sources: National Statistics Center and village statistics

Appendix 8. Total rice-growing area and actual rice cultivation area in TLM

No.	**Name of village**	**Total rice area in TLM (ha)**	**Rainy season**		**Dry season**	
			Actual rice cultivation area		**Actual rice cultivation area**	
			(ha)	**%**	**(ha)**	**%**
1	Donekoi	88.00	16.80	19.09	27.80	31.59
2	Dongkhamxang	277.00	212.20	76.61	65.10	23.50
3	Dongsavat	50.00	25.50	51.00	24.50	49.00
4	Hongkea	5.00	3.90	78.00	4.80	96.00
5	Houakhoua	54.55	5.00	9.17	41.82	76.67
6	Muengnoi	200.00	19.00	9.50	68.86	34.43
7	Nahai	210.00	27.70	13.19	12.20	5.81
8	Nonghai	71.00	25.30	35.63	46.30	65.21
9	Nonkhorneua	113.10	8.00	7.07	73.18	64.71
10	Nonvai	77.64	4.00	5.15	77.64	100.00
11	Phonpapao	80.00	40.00	50.00	54.00	67.50
12	PhonthanNeua	25.30	4.00	15.81	10.50	41.50
13	PhonthanTai	71.12	6.80	9.56	6.20	8.72
14	Salakham	38.60	11.00	28.50	27.40	70.98
15	Somsanouk	26.68	12.30	46.10	9.40	35.23
16	Thatluang Tai	12.60	6.80	53.97	6.20	49.21
17	Xiengda	33.50	8.00	23.88	33.50	100.00
	Total	1434.09	436.30	31.31	589.40	54.12

Sources: Village statistics and key informants

Appendix 9. Number of TLM households that catch fish and non-fish animals and collect vegetation

No.	**Name of village**	**Fish**		**Non-fish**		**Vegetation**	
		Rainy season	**Dry season**	**Rainy season**	**Dry season**	**Rainy season**	**Dry season**
1	Donekoi	351	315	32	50	70	60
2	Dongkhamxang	100	100	400	120	100	100
3	Dongsavat	140	140	120	0	500	300
4	Hongkea	20	10	1	1	0	0
5	Houakhoua	16	14	17	15	18	3
6	Muengnoi	200	100	150	0	40	20
7	Nahai	57	7	90	0	156	3
8	Nonghai	20	20	15	15	30	0
9	Nonkhorneua	54	98	0	25	0	5
10	Nonvai	170	25	900	0	86	30
11	Phonpapao	80	40	20	20	20	140
12	PhonthanNeua	16	9	0	0	5	2
13	PhonthanTai	40	30	35	20	25	14
14	Salakham	140	110	43	20	26	3
15	Somsanouk	240	25	48	0	12	0
16	Thatluang Tai	46	4	26	0	18	3
17	Xiengda	96	66	181	0	25	15
Total		1786	1113	2078	286	1131	698
Total households (%)		23.10	14.40	26.88	3.70	14.63	9.03

Sources: Village statistics and key informants

Appendix 10. Descriptive statistics for dry season rice production in TLM

Variables	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
Y	3.87	3.07	0.50	14.80
LA	1.18	0.87	0.25	4.50
KM	1688487	2028918	28636	12,700,000
LB	2.71	1.49	1.00	8.00
IR	10.86	21.32	0.05	133.20
AGE	51.59	13.40	24.00	90.00
SEX	1.60	0.49	1.00	2.00
EDU	6.76	3.15	0.00	16.00
IRTRA	0.43	0.50	0.00	1.00
RITRA	0.49	0.50	0.00	1.00