Irrigation Efficiencies and Water Productivity in Paddy Fields in the Lower Mekong River Basin: Application of a Water Balance Approach at Irrigation Scheme Level

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Abstract

Improving irrigation performance is a crucial issue for agriculture and irrigation development in the Lower Mekong River Basin to secure food production for people's livelihoods. Irrigation efficiency is the most important indicator to determine an irrigation scheme's performance. This study looks at water management practices and irrigation efficiency in three pilot sites in the Lower Mekong River Basin: the Numhoum scheme in Laos, the Huay Luang scheme in Thailand, and the Komping Pouy scheme in Cambodia. Irrigation efficiency and water productivity were analyzed using a water balance approach at the irrigation scheme level and results in the pilot areas show efficiencies that are definitely higher using this approach than by using the classical concept. Lower water productivity was observed at pilot schemes in areas of single cropping and higher productivity in areas where multiple agriculture activities were practiced. Strict and active water management is required to control and save water to meet agricultural demand and have sufficient water to expand cultivation areas while avoiding shortages. Promoting multiple uses of water for various agriculture activities in command area will increase water productivity.

Keywords: *irrigation efficiency, water balance, water distribution, paddy field, water productivity.*

1. Introduction

Within the Lower Mekong River Basin (LMB), agriculture is one of the largest users of water resources. The agriculture sector employs more than 80% of the population in the LMB countries (MRC, 2003) and further agricultural development is required to feed a rapidly growing population. Rice production is the single largest consumptive use of fresh water in the region.

Lack of rainfall in the dry season and low water productivity in the region are major constraints to increased rice production. Improving the performance of irrigation schemes would help farmers increase production. There is potential to expand irrigation in the LMB, but investment to upgrade existing irrigation systems, improve irrigation efficiency and water productivity is also needed.

Irrigation efficiency is an indicator of effective water resource management and this varies greatly in the LMB. It is generally low. Improving water distribution will help farmers use less water to obtain increased yields while leaving more water in the ecology and environment of the river basin, resulting in improved livelihoods in the region.

There are few reliable calculations of regional irrigation efficiencies so it is difficult to appraise efficiency trends. Previous studies conducted in the region assessed irrigation efficiency using the classical approach (Anougounamphai *et al.*, 1981; Bos and Nugteren, 1990; Thong-aram, 1995; Thanasak, 1997; Vudhivanich *et al.*, 2002; Higuchi *et al.*, 2004; Yoshida *et al.*, 2004). These studies, in the main, analyzed field level efficiencies but did not apply the water balance concept.

To help further the understanding of irrigation in the LMB, this study used the water balance approach to assess irrigation efficiency and water productivity in paddy fields, vegetable cultivation, and fish farming. A water balance analysis identifies inflows and outflows to determine the available water supply and delivered to the fields within a command area. Overall water productivity includes the total economic value per unit of irrigation water consumed.

2. Study areas

Gravity irrigation is commonly practiced in the LMB and three gravity irrigation schemes with reservoirs were selected for this study: the Numhoum scheme (Laos), Huay Luang scheme[1] (Thailand), and Komping Pouy scheme (Cambodia). Figure 1 shows their locations.

[1] The Huay Luang site is comprised of two sections of main canal and this study collected data at the left main canal only.

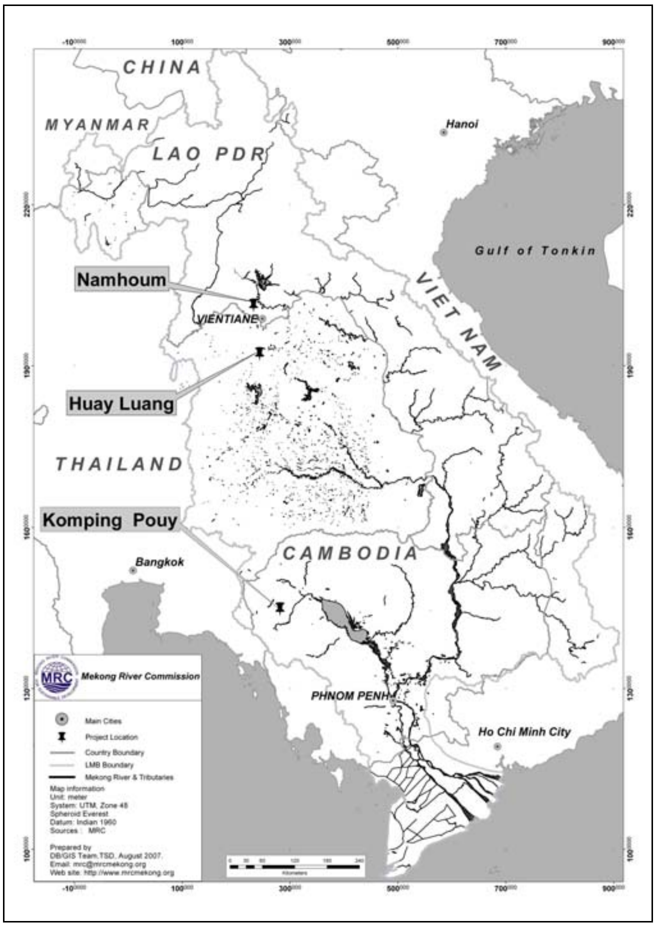

Figure 1: Location of pilot schemes

3. Methodology

3.1 Data collection

Data collection took place during one seasonal crop in the dry season period from October 2006 to the beginning of March 2007. Crop schedules varied in each scheme as shown in Figure 2. Existing information on water distribution practices in the project sites was reviewed. The ETo, ETc, rainfall, and percolation were measured on site on a daily basis by Lysimeter and simple rain gauge. The measurement of the irrigation water flow in the canal system and natural streams entering in and draining of the command areas were conducted twice a week. Cropping pattern and planted area was recorded every week and cross checked with data recorded by GPS to identify the boundary of the command area. Crop yield and prices were collected for all agriculture activities; mainly paddy, vegetables, and aquaculture which are practiced within the command area.

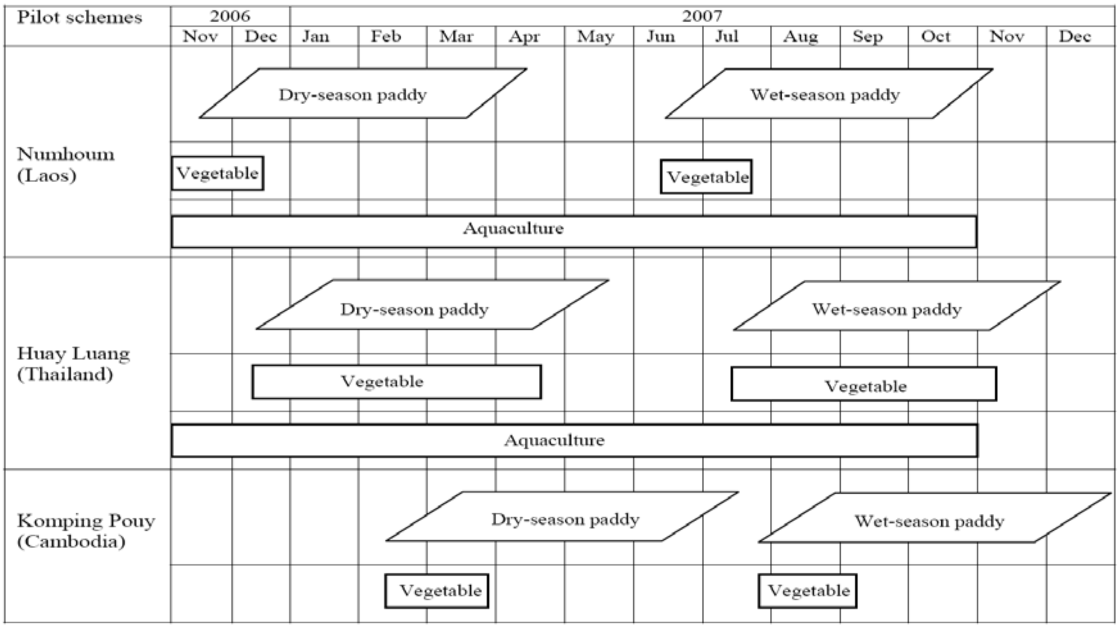

Figure 2: Crop schedule in pilot schemes

3.2 Water requirement

Because various agriculture activities are practiced in the pilot sites, the water requirement (WR in mm/d) for each agricultural practice is defined as follows (Smith, 1992; Allen, 1998).

Water requirement for paddy crops,

$$WR_p = ET_0 \times k_c + P + LP \tag{1}$$

Water requirement for non-paddy crops,

$$WR_n = ET_o \times k_c \tag{2}$$

Water requirement for fishponds and lotus farming,

$$WR_f = ET_o \times k_c + P \tag{3}$$

Where

ET_o : Potential or reference evapo-transpiration in mm/d
Kc : Crop coefficient (dimensionless)
LP : Land preparation in mm/d
P : Percolation in mm/d

The water requirements for paddy, lotus, and fishponds consider percolation. For non-paddy crops, percolation is assumed to be minor and neglectable. The ETc (ET_o x K_c) of paddy was obtained by direct measurement in the paddy field, while Kc of non-paddy crops came from FAO publications (Allen *et al.*, 1998). The standard values of 1 for fishponds and 1.2 for lotus farms are used for the water requirement calculation. For land preparation, the stand value of 3.89 mm/d for 28 days was applied in the Numhoum scheme and 6.67 mm/d for 30 days in the Huay Luang scheme (Thong-aram, 1995). In the Komping Pouy scheme, the value of 5.60 mm/d for 30 days was applied (Hara, 2001).

The total water requirement (SWR in m^3) is calculated based on the requirements for multiple uses of all agricultural activities within command area including paddy and non-paddy crops, lotus farming, and fishponds as follows.

$$SWR = \sum_{i=1}^{n} \int_{j=1}^{m} WR_{ji} \times A_{ji} \quad (4)$$

Where

i : Type of agricultural activity (e.g. paddy, non-paddy, fish farming)
j : Day
m : Number of days
n : Number of agricultural activities practiced within command area
WR_{ji} : Water requirement (mm/day x 10^{-3}) of crop type (i) at the day (j)
A_{ji} : Actual cultivated area (m^2) of crop type (i) at the day (j)

3.3 Water balance at irrigation scheme level

To ensure effective water management, it is necessary to establish where the water is going within the scheme boundary. The water balance concept provides information on all inflows and outflows in a command area and also determines the water delivery destinations, while taking into account the multiple uses of water within the command area. There were studies supporting a water balance and water accounting concept in assessing irrigation efficiency and water productivity (Molden, 1997; DNRM, 2001; Seckler *et al.*, 2003). Figure 3 shows the water balance components in an irrigation scheme.

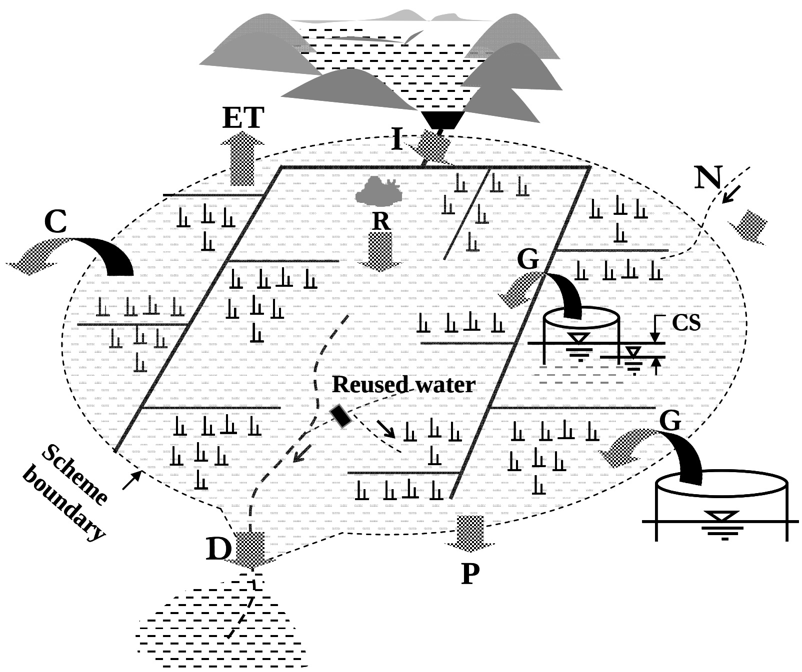

Figure 3: Water balance component

From Figure 3, water balance is defined as follows.

$$AWS = (R + I + N + G - CS) - (ET + P + D + C) \quad (5)$$

Where

AWS : Available water supply within command area (m^3)
R : Rainfall (m^3)

I : Intake from main canal (m^3)
N : Natural flow entering command area (m^3)
G : Deep ground water from inside and outside command into the command area (m^3)
CS : Changes in storage or recharge of percolation and ground water use (m^3)
ET : Evapo-transpiration (m^3)
P : Percolation (m^3)
D : Drain water to sinks outside and without reuse or non-utilizable water supplies (m^3)
C : Committed flows to the other areas, for example legally or conventionally committed outflows from command areas to outside (m^3)

The changes of storage (CS) and ground water inflows (G) are not considered in the analysis because no significant ground water is used in the pilot schemes.

3.4 Overall command area efficiency

With the concept of water balance, inflow and outflow are computed and once conveyance efficiency is calculated, overall project command area efficiency is then computed as follows.

$$E_{overall} = \frac{SWR - ER}{WDF} \times 100 \tag{6}$$

Where
SWR : Total scheme water requirement (m^3)
ER : Effective rainfall (m^3) which is calculated using FAO formulas (Thong-aram, 1995) as follows.

$$ER = \sum_{i=1}^{n} \left[10 \times A_i \times (1 - 0.006 R_i) R_i \right] \tag{7}$$

Where
i : Day
n : Number of days
A_i : Actual cultivated area (ha) on data collection day (i)
R_i : Rainfall (mm) data collection day (i)

WDF : Total water delivered to the fields (m^3) which is defined as followed

$$WDF = (I \times E_c + N) - (D + C) \tag{8}$$

Where
I : Total diversions or surface inflows from irrigation canal into the command area (m^3)
E_c : Conveyance efficiency (%) in equation (9)
N : Total natural flows entering command area (m^3)
D : Drain water to sinks outside and without reuse or non-utilizable water supplies (m^3)
C : Committed flows to other areas (e.g. legally or conventionally committed outflows from command areas to outside (m^3)

Committed flows are considered in cases where an irrigation network transports water downstream through a command area. There are no committed flows in the pilot sites.

3.5 Conveyance efficiency

Calculating the volume of lost or mismanaged water is necessary for improved water management and for securing proper water delivery to the users.

The conveyance efficiency (E_c in %) is an indicator of this effectiveness and is determined as follows.

$$E_C = \frac{\sum_{i=1}^{n} Q_{out}}{\sum_{i=1}^{n} Q_{in}} \times 100 \quad (9)$$

Where

i : Inlet and outlet of the canals

n : Number of inlets and outlets of the canal when conducting conveyance loss test

O_{ut} : Water flowing out of the canal section (m^3/s)

Q_{in} : Diverted water into canal (m^3/s)

The conveyance test was conducted using long distances at three canal levels (main, second and tertiary) by measuring all inflows and outflows at each canal level from the beginning to the end of the irrigation period. Two or three second-level canals, tertiary canals, and farm ditches were selected as representative for the schemes.

3.6 Water productivity

Greater production with the same volume of water is the primary objective[2] of irrigation water management. Water productivity is one of the significant values to determine that water is used efficiency. There are several definitions to calculate water productivity, but in this study, water productivity (WP) is defined (in USD/m^3) as the economic value of all agriculture activities per one unit of available water supply within a command area (Burt, 2002) and calculated as follows.

$$WP = \frac{Value\ of\ \ total\ output\ (USD)}{AWS(m^3)} \quad (10)$$

Where

Value of total output : The total production value in the command areas calculated as USD

AWS : Available water supply (m^3) in equation (5)

4. Results and Discussions

4.1 Observed data

Figure 4 (a) shows the results of observed field data during one dry season crop in the Numhoum, Huay Luang, and Komping Pouy schemes. The data observed include daily rainfall, evapo-transpiration, and percolation rate in mm per day.

Rainfall**:** Rainfall during the dry season is generally low at the pilot schemes with averages of only 0.7 mm/d in the Numhoum scheme, 2.73 mm/d in Huay Luang, and 4.15 mm/d in Komping Pouy. Higher rainfall was observed in the scheme located at the lower area of the basin (Komping Pouy) and the lowest rainfall was recorded in the Numhoum scheme located at the most upstream of the pilot areas. The peak rainfall period during dry season occurs between April and May.

ETc**:** Evapo-transpiration (ETc) was observed during different periods in the pilot schemes depending on their cropping patterns. The daily average ETc observed in the Numhoum scheme was 3.22 mm/d which is relatively low compared to the standard value (6.97 mm/d) used by many irrigation water management schemes in the Vientiane Plain. This value (6.97 mm/d) is used in Nongkai province of Thailand and there is no specific experiment determining the ETc for Laos. The highest value of ETc recorded was 4.7 mm/d in the middle of February to early March. This value is significantly lower compared to Thailand and Cambodia. In the Huay Luang scheme, the ETc was 5.03 mm/d which is highest among the three pilot sites. The variation of ETc through the crop season is rather clear between the initial and development periods. The recorded ETc is under 5 mm/d mainly from January to February and above 5 mm/d February to March. The average value

[2] The phrase – More Crop per Drop – is often used to describe this objective.

of 5.03 mm/d seems reliable compared with the values being used in Northeast Thailand with 5 to 9 mm/d in dry season and 4 to 7 mm/d in wet season (Thong-aram, 1995). The highest percolation value was observed in Cambodia. The high ETc (higher than 5 mm/d) occurs mainly in March and April when the hottest period in the dry season. The daily average of ETc is recorded as 4.76 mm/d which is similar to the value (5mm/d) being used by project site.

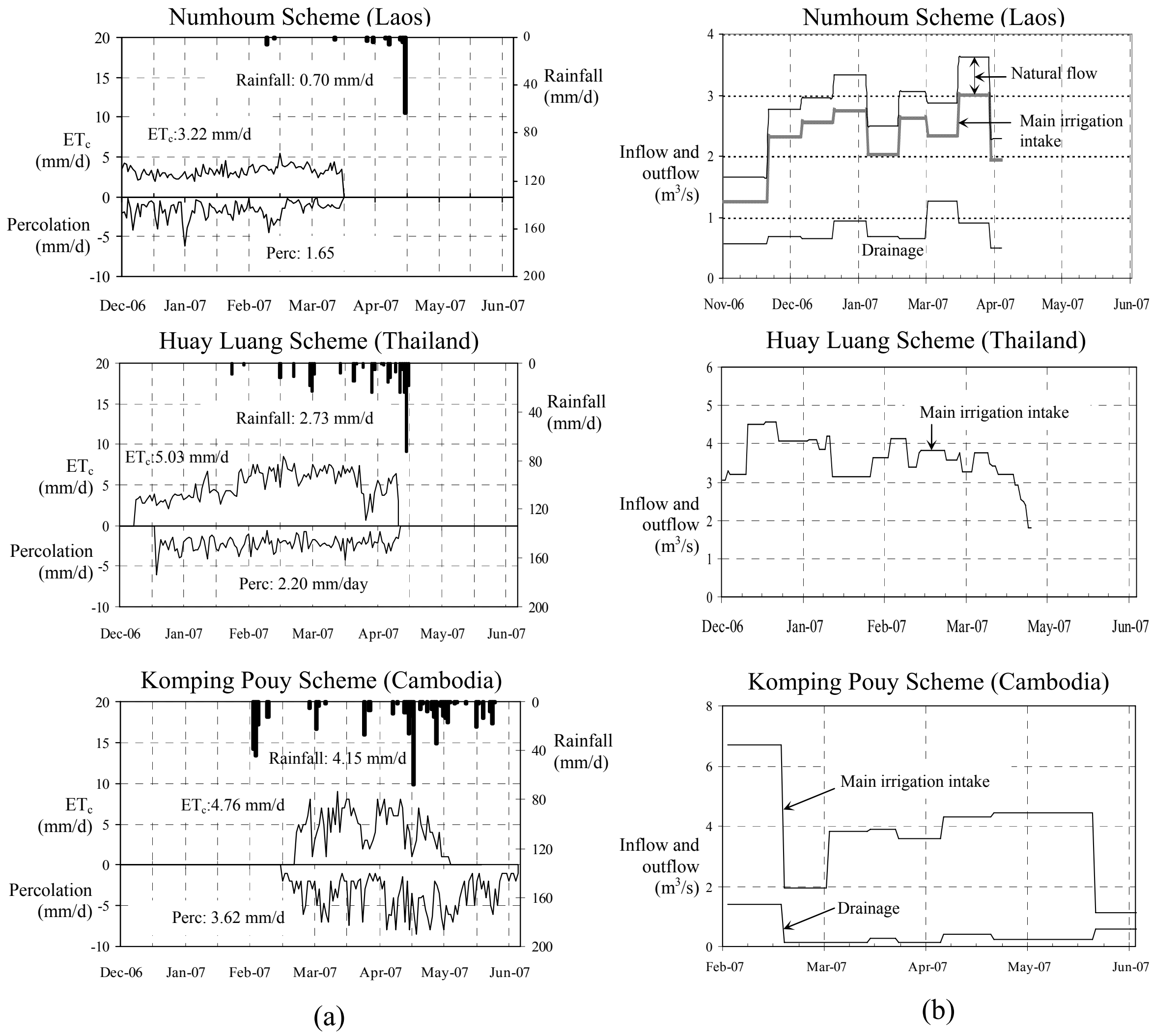

Figure 4: Data observed in the fields

Percolation**:** Percolation rates were recorded near the same time as ETc. The same as the ETc values, the percolation rate is low in Numhoum with an average of 1.65 mm/d. The highest value observed was January and middle of February with more than 3 mm/d and the lowest value is observed at the late stage of the crop season. Percolation in the Huay Luang scheme seems constant through the whole season, except at the beginning which averaged 2.2 mm/d. The observed data is slightly higher than the standard value (2 mm/d) in Northeast Thailand which is determined by the Royal Irrigation and Department (RID) of Thailand.

The highest percolation rate among the pilot schemes was recorded in Komping Pouy with an average of 3.62 mm/d for whole dry season crop. The rate fluctuates through the crop season reaching 6 to 7 mm/d at the peak time in the middle of April, but lower than 2 mm/d from the middle of March to the end of April.

***Surface inflows and outflows*:** Figure 4 (b) presents daily surface inflows and outflows of scheme boundaries. In the Numhoum scheme, the lowest water supply was at the initial cultivation stage, nursery, and land preparation periods. The water supply steadily increased after transplanting (December to the middle of January). It declined between the middle of January to March when farmers apply fertilizer. The peak rate of 3 m^3/s occurs in the middle of March at the crop flowering stage. The total surface inflows of this scheme (Table 1) are 31.56 MCM which accounts for 82.95% from main canal intake, while 16.98% comes from natural rivers, and only 0.05% from precipitation. The total outflows are 16.47 MCM of which more than 50% is outflow flow from drainage canals. It is observed that the trend of surface outflow changes in accordance with inflows from the main canal from the beginning to the middle of February; that is, the more irrigation water supplied, the more water is drained out. It is important to save irrigation water from the reservoir by observing the peak outflow occurring in the middle of February. The significant difference between water demand and supply during this period is important data observed which can help to improve water management.

In the Huay Luang scheme, the inflow was considered only at the main intake by the irrigation canal while natural streams were not counted because these are not used for irrigation water within the command area. There is no drainage canal since the end spill points of canals are designed connecting to the paddy field. Therefore, outflows are also not considered and are assumed to equal the natural river inflows. The peak water supply of 4.6 m^3/s was observed in January during land preparation and the minimum supply of 3.1 m^3/s occurred in February. The water supply begins to decline at the end of the cultivation period when the harvested stage starts. The total inflows given in Table 1 are 48 MCM, around 80% is from main intake, and the remainder is from rainfall.

In the Komping Pouy scheme, the inflows were observed at both canals and natural streams. However, the streams were dry because of the limited rainfall in dry season. The inflow from stream lines will be calculated later during wet season observation. Only inflows from the main canal are counted in this calculation. As shown in Figure 4(b), the project takes water as a peak rate of nearly 7 m^3/s at the beginning during land preparation period while the peak drain also occurred in the same period. The project takes minimum water in February with only 2 m^3/s. The total inflows are calculated as 50.94 MCM, mainly from main canal. The total outflows in Table 1 are 20.99 MCM with a large proportion caused by ET. The surface outflow is largely dependant on irrigation water. Large volumes of irrigation water is unused and drained out at the beginning. To save water, the project staff should reduce water supplied in this period.

4.2 Water balance

Table 1 summarizes components of all inflows and outflows. The inflows are mainly from irrigation canals, with only small contributions from rainfall (e.g. 0.05% for the Numhoum scheme, 20.40% for Huay Luang, and 13.13 % for Komping Pouy). There is no inflow from natural rivers except in the Numhoum scheme with approximately 17% of total inflows. The large proportion of outflows occurs by drainage at Numhoum, while it is largely caused by ET at the Huay Luang and the Komping Pouy schemes. Less occurs through deep percolation with 17% of total inflows in the Numhoum scheme, 27% in Huay Luang, and 32 % in the Komping Pouy schemes.

Table 1 also reports the available water supply within the command area - 15.08 MCM, 28.30 MCM, and 29.96 MCM for the Numhoum, Huay Luang, and Komping Pouy schemes respectively. These volumes are used to calculate water productivity. With unit of available water supply, the Numhoum and the Huay Luang schemes are similar at 74.89 m^3/ha/day and 77.63 m3/ha/day. These schemes use intensive water management to allocate sufficient water through whole command area. The Komping Pouy scheme, however, is more than double at 156.26 m^3/ha/day.

Figure 4(b) shows that nearly 7 m3/s is supplied at the peak time in February while 3 m^3/s in the Numhoum scheme although with similar size of the command area.

Table1: Water balance components

Water balance in the scheme level		Pilot schemes		
		Numhoum	Huay Luang	Komping Pouy
Inflow	Precipitation, ∑R (MCM)	0.02 (0.07%)	9.79 (20.40)	6.69 (13.13%)
	Intake from main canal, ∑I (MCM)	26.18 (82.95%)	38.21 (79.60%)	44.25 (86.87%)
	Natural rivers, ∑N (MCM)	5.36 (16.98%)	0.00 (0.00%)	0.00 (0.00%)
Total inflow		*31.56*	*48.00*	*50.94*
Outflow	∑ET(MCM)	4.90 (29.75%)	14.33 (72.74%)	9.31 (44.36%)
	Percolation, ∑P (MCM)	2.74 (16.64%)	5.37 (27.26%)	6.78 (32.30%)
	Drainage, ∑D (MCM)	8.83 (53.61%)	0.00 (0.00%)	4.90 (23.34%)
	Committed flow, ∑C (MCM)	0.00 (0.00%)	0.00 (0.00%)	0.00 (0.00%)
Total outflow		*16.47*	*19.70*	*20.99*
Available water supply, AWS (MCM)		**15.08**	**28.30**	**29.960**
Irrigation days (days)		132	122	132
Actual planted area (ha)		1,525.49	2,987.84	1,452.50
Unit available water supply (m^3 /ha/day)		**74.89**	**77.63**	**156.26**

4.3 Conveyance efficiency

Table 2 provides the results of conveyance efficiency in the three pilot schemes which was conducted by recording the flow data in each canal level intensively for the whole irrigation period.

The lowest conveyance efficiency is found in the Numhoum scheme with 69.27%. The scheme has earth type irrigation canals in poor condition, and not rehabilitated in 20 years resulting in much leakage along canals. The value is also low compared with other irrigation schemes in Laos e.g. 87.8% in the Kao Leo II scheme (Thanasak, 1997) and 79% in the KM 6 scheme (Yoshida, 2004). The highest conveyance efficiency was observed in the Huay Luang scheme with 88.46%. Here, the canal system is equipped with a lining and there is good maintenance.

In the Komping Pouy scheme, the conveyance efficiency is 75.44% which is higher than the Numhoum scheme although it has the same earth type canal. The system was rehabilitated in 2002.

Table 2: Conveyance Efficiency

Pilot schemes	**E_c (%)**
Numhoum	69.27
Huay Luang	88.46
Komping Pouy	75.44

4.4 Overall command area efficiency

Table 3 explains the results of the overall command area efficiency in the three pilot schemes, The water requirements shown in Table 3 are calculated using equations (1) to (4). The ETc, percolation, and surface inflow and outflows shown in Figure 4 are used to calculate scheme water requirements and water delivered to the fields.

The total requirements calculated for the Komping Pouy scheme is double that of Numhoum although the irrigated areas of these two schemes are similar. This is caused by the high percolation and evapo-transpiration occurring in the Komping Pouy scheme. The effective rainfall is rather high in the Huay Luang and the Komping Pouy schemes where higher rainfall and larger catchment area (irrigated area) in the Huay Luang scheme. The total water delivered to the fields shown in Table 3 is calculated by using equation (8).

The overall command area efficiency is generally high in the pilot schemes compared to previous studies conducted on other irrigation schemes in the same region e.g. 47.17% in the Kao Leo II scheme (Thanasak, 1997), 58% in KM6 scheme in Vientiane, Laos (Yoshida, 2004), 65% in an irrigation scheme in Northeast Thailand (Thong-aram, 1995), and around 40% to 60% at the Chao Praya area of Thailand (Vudhivanich *et al.*, 2002). The reason for the high efficiency in this study is the result of using the water balance approach.

The water balance approach considers the water volume delivered to the fields while taking into account multiple water uses and additional irrigation water reused from natural streams. With this approach, efficiency is defined as the ratio of the net water used by the crops and water delivered to the fields which extracting drained water and deep percolation, while efficiency under the classical concept is determined by net water used by the crops and water input by at main intake from reservoir.

As shown in Table 3, the lowest efficiency appeared in the Komping Pouy scheme with 62.73%. The scheme has a large canal compared to the size of cultivation area which needs large volumes of water to keep water levels high. This results in the low efficiency. Although large volumes of water are supplied into the command area, a downstream water shortage is still observed. Large volumes of water drain out of the command area through drainage canals. Therefore, strict water management needs to be implemented to control water distribution more efficiently.

However, higher efficiencies were observed at the Numhoum and Huay Luang schemes where water is better managed. Although the Numhoum scheme has an irrigation canal in poor condition making it difficult to control water properly, water management at the farm level is actively practiced. The water is reused by taking water from drainage canals and the rotation method is applied for water management between water management zones.

The Huay Luang scheme's canals and irrigation infrastructure are in good condition and they have more advanced skills in water management. The rotation method is applied not only for each management zone, but also in each canal level, from the main down to the farm level. The staff receives government supported incentives for water management activity and this results in a high participation on water allocation monitoring and evaluation leading to the high efficiency. To save water, the project limited the area for rice cultivation, instead promoting non-paddy crops in the command area.

Table 3: Overall command area efficiency

Pilot schemes	Scheme water requirement (MCM)	Effective rainfall (MCM)	Water delivery to the fields (MCM)	Overall command area efficiency (%)	Canal type
Numhoum	9.30	0.12	13.02	**70. 52**	Earth
Huay Luang	24.94	0.69	33.80	**71.74**	Concrete lining
Komping Pouy	18.52	0.66	28.48	**62.73**	Earth

4.5 Water productivity

Water productivity results are reported in Table 4. The value of water use efficiency is calculated by values (USD) of the total production per unit of available water supply. The total production from multi-agriculture activities is counted on paddy, vegetables and aquaculture, while the other production is minor and not counted.

The results show that the highest water productivity was obtained in the Huay Luang scheme with USD 0.123/m^3. The cultivated area is not mostly dependant on paddy, but also diversification crops (more than 32% of the total area) and aquaculture (5%). Vegetable usually fetch higher prices and consume less water. Vegetable yields are also comparatively high.

The lowest water productivity was observed at the Komping Pouy scheme with USD 0.040/m^3. The cultivated area is mainly paddy with a small percent in vegetables (0.5%). Although with the large volumes of available water in the scheme, the total value of production is not high. The yield of paddy is also similar to other schemes, even higher than Huay Luang.

In the Numhoum scheme, water productivity was USD 0.091/m^3. The value is also high compared to the Komping Pouy. The cultivated area is combined with vegetable around 1.2% and livestock and aquaculture more than 1.4%. The yield of paddy in this scheme is relative high among three pilot sites. The yields and prices of paddy in each pilot site are similar, while different for vegetables and fish farming. Vegetables usually fetch higher prices than paddy and consume less water.

Table 4: Water productivity

Pilot scheme	Production			Available water supply (MCM)	Water Productivity (US$/$m^3$)
	Production Type	Yield (T/ha)	% of total command area		
Numhoum	Paddy	3.88	97.35	15.08	**0.091**
	Vegetable (cucumber)	2.54	1.23		
	Livestock (fish and chicken farming)	4.07	1.42		
Huay Luang	Paddy	3.50	62.82	28.30	**0.123**
	Vegetable	18.28	32.19		
	Fish and lotus farm	10.25	4.99		
Komping Pouy	Paddy	3.71	99.50	29.96	**0.040**
	Vegetable (sweet corn)	2.30	0.50		

Note: production price is based on data from 2006-07

5. Conclusion

In this study, irrigation efficiency and water productivity were analyzed using the water balance approach to gain accurate insights into the quality of water management practiced in the pilot schemes as well as providing data that can be used in other areas in the LMB.

The results showed that all three sites demonstrated a high degree of efficiency even though some schemes have earth type canals in poor condition. The main reason for this is because using the water balance approach which definitely shows the lower volumes of available water delivered to the fields rather than the classical concept. A higher efficiency was observed in schemes with active and strict water management with a high degree of monitoring and evaluation of water allocation. Sites with low efficiency had poorly designed hydraulic structures allowing excessive water into command areas and then drain out without being used.

Water productivity captures the performance of water use by providing total output values per unit of available irrigation water. High water productivity is found in schemes practicing multiple agriculture activities, while the low water productivity is observed at schemes practicing single crop.

Based on the primary results obtained from the efficiency and water productivity assessment, strict and active water management is required to reach the maximum amount of cultivated area without water shortages affecting production. For schemes with too large capacity canals, enlarging cultivated areas where possible needs to be considered; otherwise irrigation water in the canal is drained out of command areas without being used. Combining cultivated area with multiple agriculture activities is also essential for increased water productivity.

In line with the Mekong River Commission’s Strategic Plan 2006-2010 which supports the effective use of the Mekong's water and related resources to alleviate poverty while protecting the environment, efficient use of irrigation water is a priority if gains in crop production are to be realized. This study will continuously examine wet season crops in the three pilot sites.

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