The Potential Allocation for Dry Season Crop-Area Planning, the Huai Luang Operation and Maintenance Project, Thailand

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Abstract—This study comprised optimization process for finding crop-area planning in dry-season and the application of optimization program using Linear Programming (LP) to solve optimal area planned in dry-season. The study area was applied to left and right main canal system of Huai Luang Reservoir, Thailand. The calculation data obtained from dry year (2003), normal year (2001) and wet year (1996). The analysis created condition objective function and constraint functions. The constraints consisted of the constriction of area characteristic, irrigation water requirement, water availability, cropping-area of each Irrigation Zones, capacity of Left and Right Main Canal System of Huai Luang Reservoir, capacity of canal in Irrigation Zones and cropping pattern alternatives. The results found that LP was functioned for finding cropping and setting area for dry-season planning. The comparison results from alternative plans found that the areas obtained from first alternative plan which undivided area, it was founded that optimal area was less than that obtained from the second alternative which divided area about 12.62% 11.35% and 4.87% for dry year, normal year and wet year, respectively. Hence, allocation potential for dry season crop-area planning were 4,531.20 ha, 6,574.08 ha and 7,116.64 ha for dry year, normal year and wet year, respectively. The results from equations could made graph of relationship between the areas obtained from equation and the sum of water capacity in Huai Luang reservoir, it found that the graph was functioned well to optimize cropping and setting area for dry-season planning in the further year. The results of testing in 2011/2012 also showed that the difference of the solutions obtained by graph and the cropping area results in main canal system was 4.53%.

Keyword- Crop-area planning, Optimization programming, Water allocation, Huai Luang Reservoir

I. INTRODUCTION

Nowadays, water resources management within irrigation project area is one of the classical water resource problems. Crop-area planning of the irrigation project is the land-area that provided for growing each crops at the beginning of seasonal cultivation [1,2,3]. Generally, crop-area plan is created following the size of land area that used to be cultivated in the previous season. The new available water budget, farmer experience and farmer need are rarely considered to plan. So, several crop-area plans are not accepted to perform by farmers. Therefore, the farmer needs to have the optimum crop area-plan which suitable for available water budget, land area constraint and the farmer need.

A linear programming (LP) is an optimization technique which widely used to solve allocation problem. The popular application of the LP technique in the water resource problems is to find an optimal seasonal crop pattern subjected to limited available resources [4, 5, 6]. The maximization profit was set as the objective function subjected to the resource constraints such as available water, crop price, man power, pesticide, crop water requirement etc. The objective function and constraint functions are formulated as linear equation for solution searching. The portion of treated water from waste water treatment and ground water was considered into the water constraints of the LP model [7]. Moreover, water quality parameters were also incorporated into the LP model [8]. Moreover, a pricing of irrigation water was considered in the constraints of LP model [9]. The available water that divert from the reservoir is the necessary constraint in water allocation and distribution [10]. However, the obtained result is difficult to perform because the farmer still to grow the same type, the same area and respond their needs. The maximum land area target that possible grow under the available water at the beginning season is requested by farmer who have the plan to cultivate in next season.

The objective of this paper is to apply a LP model for finding crop-area planning in dry-season. The sum of maximum cultivated area of the irrigation project is an objective function subjected to available water budget and land area under canal capacity. The LP model is applied with the Huai Luang operation and maintenance project, Thailand. The alternative plans based on both shared area first and without shared area are presented in this study.

II. METHODOLOGY

A. Linear programming for searching crop-area planning

The linear programming was used to find the maximum cultivated area in dry seasonal crop-planning. The model was formulated to maximize dry seasonal crop-area (*A*) subjected to the limited resources on available dry-season water and crop water requirement, land area of each zone, cropping intensity and canal capacity. Decision variables were cultivated area of each crop. The objective function of the model can be presented as:

$$Max A = \sum_{i=1}^{I}\sum_{j=1}^{J} A_{ij} \qquad (1)$$

where *A* is the sum of cultivated area of the irrigation project (hectares, ha), A_{ij} is cultivated area of crop *i* in zone *j* , *j* is zone area (*j*= 1, 2, 3, 4), *i* is water requirement type (paddy, farm plants, vegetable and fish pond).

The constraints of the model can be divided into two categories including amount of water constraint and land area constraint.

For the land area constraint, the summation area of cultivated area of all water requirement types in zone *j* is not greater than the available area of the zone *j*, which described as:

$$\sum_{i=1}^{4} A_{ij} \le A_j;\ \text{for } j=1, 2, 3, 4 \qquad (2)$$

The net water requirement is not greater than the total available water of the irrigation system (canal capacity in left and right main canal) multiplying the irrigation efficiency of the irrigation project, which described as:

$$\sum_{i=1}^{4}\sum_{t=1}^{T} WR_{it} \times A_{ij} \le B_c \times IE_2;\ \text{for } j=1, 2, 3, 4 \qquad (3)$$

$$\sum_{i=1}^{4}\sum_{t=1}^{T} WR_{it} \times A_{ij} \le C_c \times IE_1;\ \text{for } j=1, 2, 3, 4 \qquad (4)$$

$$\sum_{i=1}^{4}\sum_{t=1}^{T} WR_{it} \times A_{ij} \le W_t \times IE_2 \times F_t;\ \text{for } j=1, 2, 3, 4 \qquad (5)$$

$$\sum_{i=1}^{4} A_{ij} \ge K \times A_j;\ \text{for } j=1, 2, 3, 4 \qquad (6)$$

$$A_{ij} \ge 0 \qquad (7)$$

where

where	WR_{it}	=	water requirement of crop *i* during week *t* (m^3)
	B_c	=	capacity of left and right main canal for each span *c* (m^3)
	C_j	=	capacity of canal in zone *j*
	EI_1	=	irrigation efficiency in zone area
	IE_2	=	irrigation efficiency in main canal
	F_t	=	percent of water use for agriculture during week *t* (%)
	K	=	distribution coefficient to zone area
	W_t	=	available water divert to main canal during week *t* (m^3)

The cultivated area of crop *i* in zone *j* that obtained from the model was presented on geographic information system (GIS). Fig.1 shows the location and irrigation area of the Huai Luang operation and maintenance project during dry season. It indicates that all canal lines are provided available water from the reservoir cover the irrigation area.

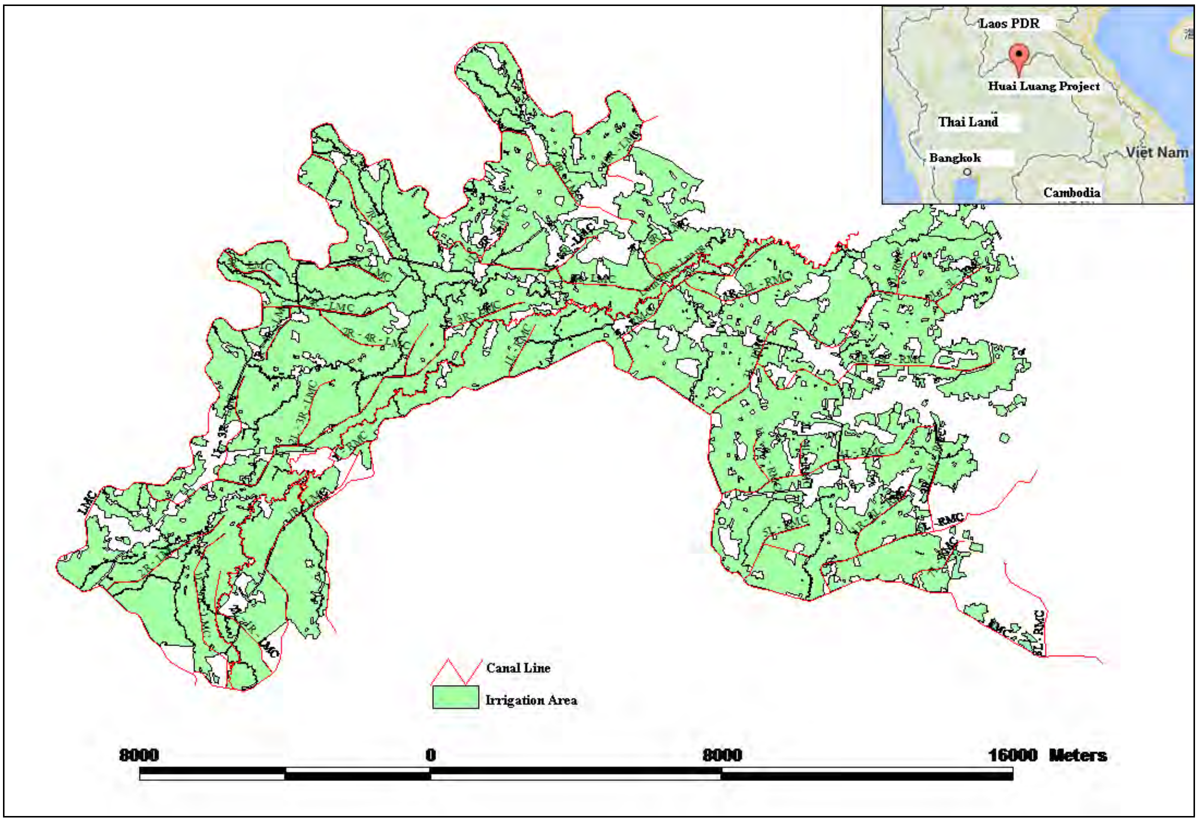


Fig. 1. Irrigation area during dry season of the Huai Luang Operation and Maintenance Project

B. Alternative plan of cultivation in dry season

Generally, paddy is main crop for farmer in this irrigation project because they had being grown for a long time. The cultivated area of paddy is 25% of all irrigated areas. Nowadays, paddy irrigation areas are increasing that over plan. Crop area planning is difficult to fully use because there are many factors such as crop price, farmer habit on cultivation and characteristic of soil type. Hence, this study divided alternative plan into 2 plans.

The first alternative plan is cultivation without share area of each zone. The cultivation of each zone can be done depend on potential area.

The second alternative plan is cultivation by share area of each zone (there are 4 zones in the irrigation project). This plan allocated water to all zones by 50% first, then 50% remain will be grown in 4 weeks later. Fig. 2 shows the zones of available area for cultivation. It indicates that the first blue area of zone 22, then the green area of zone 22, next the pink area of zone 11 and the last orange area of zone 12.

The farmers are familiar to growth in both 2 alternative plans. The water requirement of paddy, farm plants, vegetable and fish pond of the second alternative plan are 396.72 mm. 314.28 mm. 139.21 mm. and 921.08 mm. respectively. These values were used to calculate the multiply factor of each water use type as compared with water requirement of paddy as 1.27, 2.86 and 0.43 for farm plants, vegetable and fish pond respectively. The multiply factor of paddy per farm plants is 0.79, paddy per vegetable is 0.35 and paddy per fish pond is 2.31. These factors can be used to convert a water requirement type to the others.

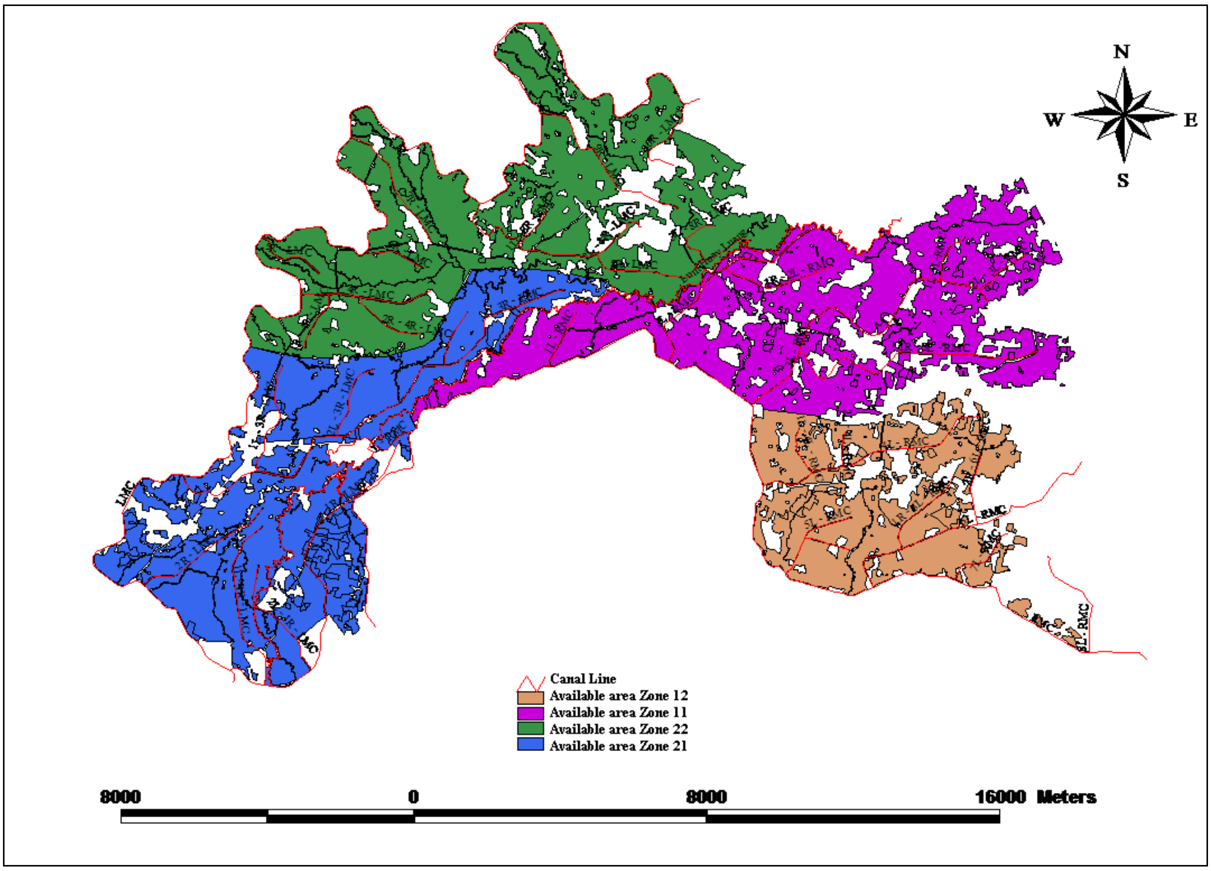


Fig. 2. The zones of available area for cultivation of the Huai Luang Operation and Maintenance Project

C. The illustrative application

The Huai Luang Reservoir, is a large reservoir under the Royal Irrigation Department responsibility. It covers an area of some 3,200 hectares (ha) with the capacity of 113 million cubic meters (MCM) for water. It feeds 13,760 ha of agricultural area and also serves as a source of water for animals, crops and public water supply. Fig.1. shows the location of the Huai Luang Reservoir in the Northeast region of Thailand.

The Huai Luang irrigation system has an estimated irrigation service area of 13,760 ha during wet season and 3,200 ha during the dry season. The main, the secondary and the tertiary canals are good functional.

III. Results and Discussion

A. Optimal crop-area planning

The LP model was applied to find the maximum total cultivated area using available water of December. These 3 cases of dry year, normal year and wet year were used to apply for searching cultivated area of each zone. Table 1 present the estimated area of each zone when using the first alternative plan. They indicated that the total cultivated area of dry year, normal year and wet year are 4,024 ha, 5,904 ha and 6,786 ha respectively. Table 2 present the estimated area of each zone when using the second alternative plan. They indicated that the total cultivated area of dry year, normal year and wet year are 4,531 ha, 6,574 ha and 7,117 ha respectively.

TABLE I
Estimated area of each zone when using the first alternative plan (ha)

Zone area (Aij)	Dry year	Normal year	Wet year
A11	1,266	1,858	2,136
A12	474	695	799
A21	1,628	2,388	2,745
A22	656	962	1,106
Total	4,024	5,904	6,786

TABLE II
Estimated area of each zone when using the second alternative plan (ha)

Zone area (Aij)	Dry year	Normal year	Wet year
A11	1,426	2,069	2,240
A12	533	774	838
A21	1,833	2,659	2,879
A22	739	1,072	1,160
Total	4,531	6,574	7,117

B. Comparison of estimated area from the first and the second alternative plans

The estimated area obtained from the first and the second alternative plans are presented in Table 3 and Fig.3. These are guideline for the farmer to growth in next season. The model was applied for 3 cases of dry year, normal year and wet year. They indicate that the obtained results of the second alternative plan are higher than the results of the first plan. Hence, the second plan was selected to use in next step.

TABLE III
The sum of crop-area planning from the first and the second alternative plan (ha)

Year	Estimated Area from the first alternative plan (ha)	Estimated Area from the second alternative plan (ha)	The differences (%)
Dry year	4,024	4,531	12.62
Normal year	5,904	6,574	11.35
Wet year	6,786	7,117	4.87

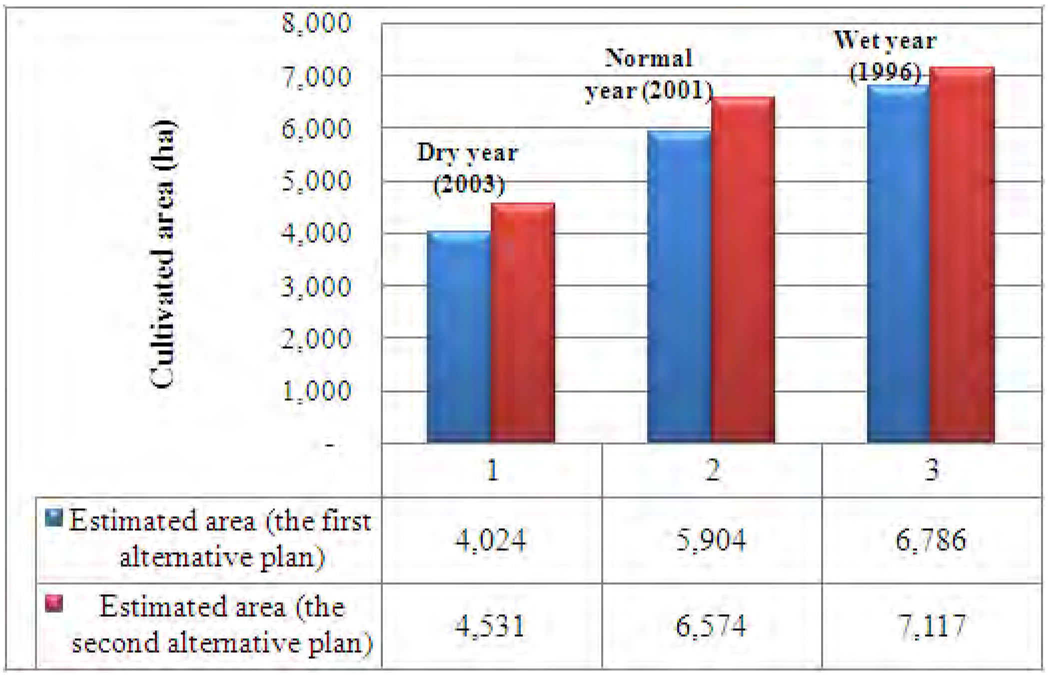


Fig. 3. The obtained crop-area planning of the first and the second alternative plans

They can conclude that if farmer cultivate without shares area zone in the first plan, they will cultivate slightly only. If the farmer cultivate 50% of the target area first and then cultivate more 50% remain based on the second plan, they will cultivate increasingly. In addition, cultivation by shared area first followed the available water promotes the farmer find water for plant from the other sources.

Fig. 4 shows the obtained crop-area planning of the second alternative plan and the actual cultivated area in dry yea, normal year and wet year. It indicates that the estimated areas from the second plan are greater than the actual cultivated area for all cases. For this reason, when the farmer cultivated 50 % of target area first, they can growth more area increase to 50% remains.

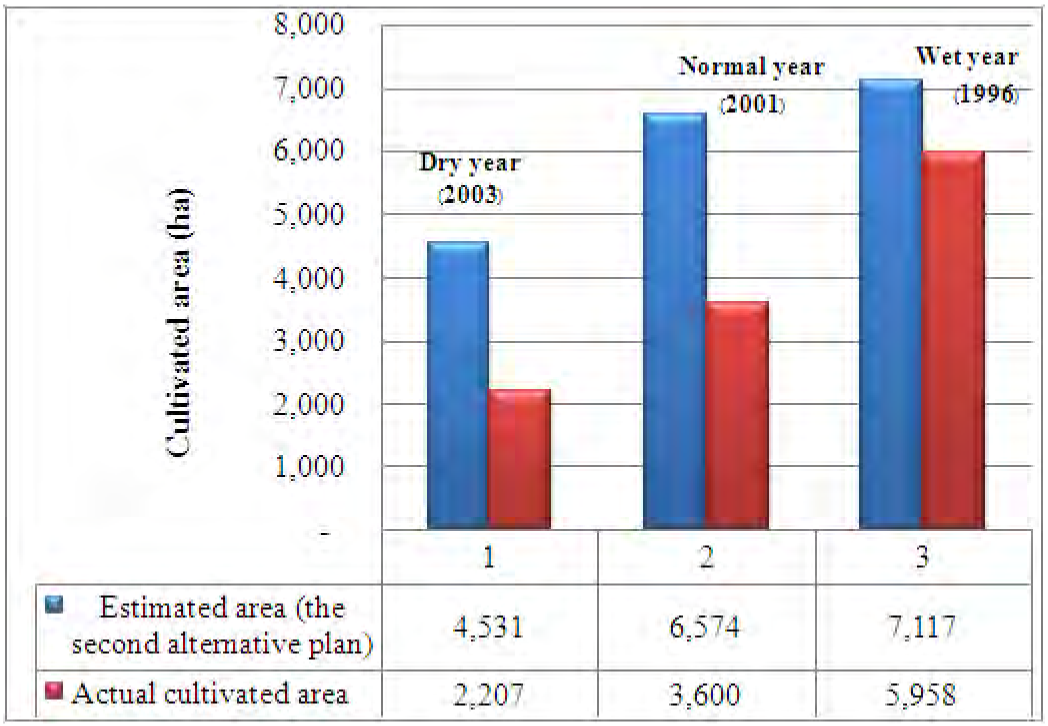


Fig. 4. The obtained crop-area planning of the second plan and the actual cultivated area

Fig. 5 shows the relationship between available water and cultivated area of each zone. These graphs were created from the second alternative plan. They present that the cultivated area is increase along with the increasing of available water for all area zones.

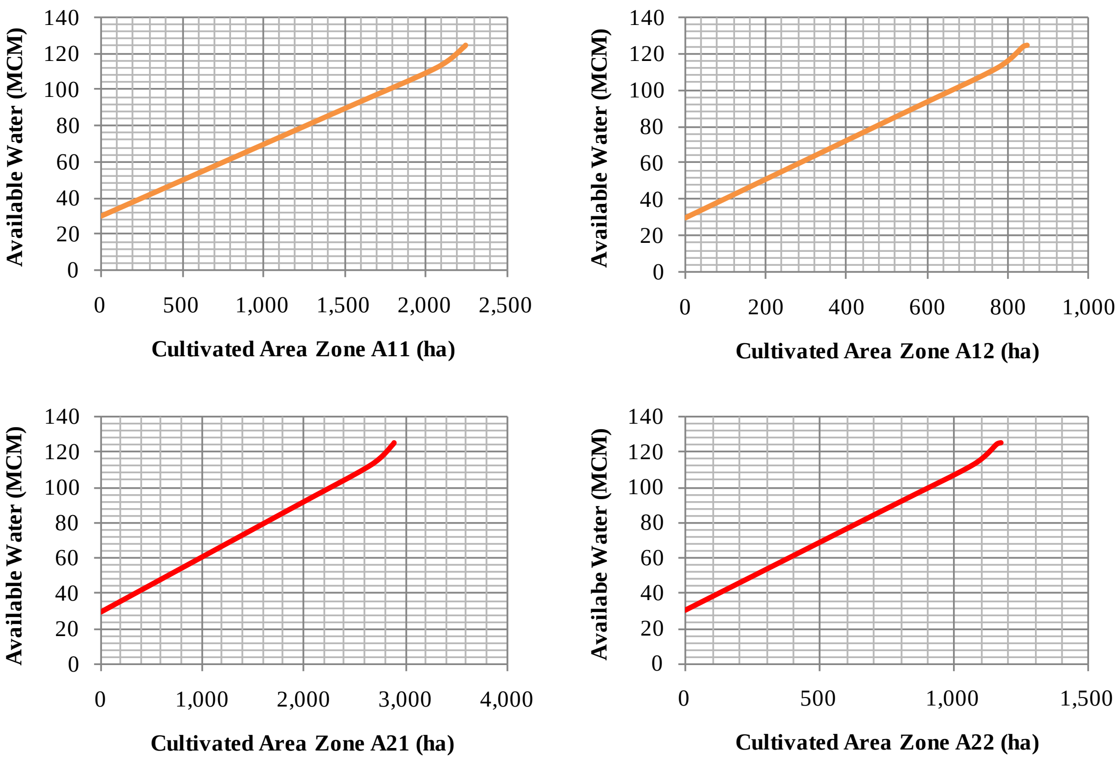


Fig. 5. The relationship between available water and the estimation of cultivated area zone

The comparison between actual cultivated area and estimated area was done for evaluating the efficiency of the method. Fig. 6 shows the estimated area of each zone for the Huai Luang operation and maintenance project during dry season using information of 2011/2012. It indicates that the cultivated areas of each zone are closed to the canal lines.

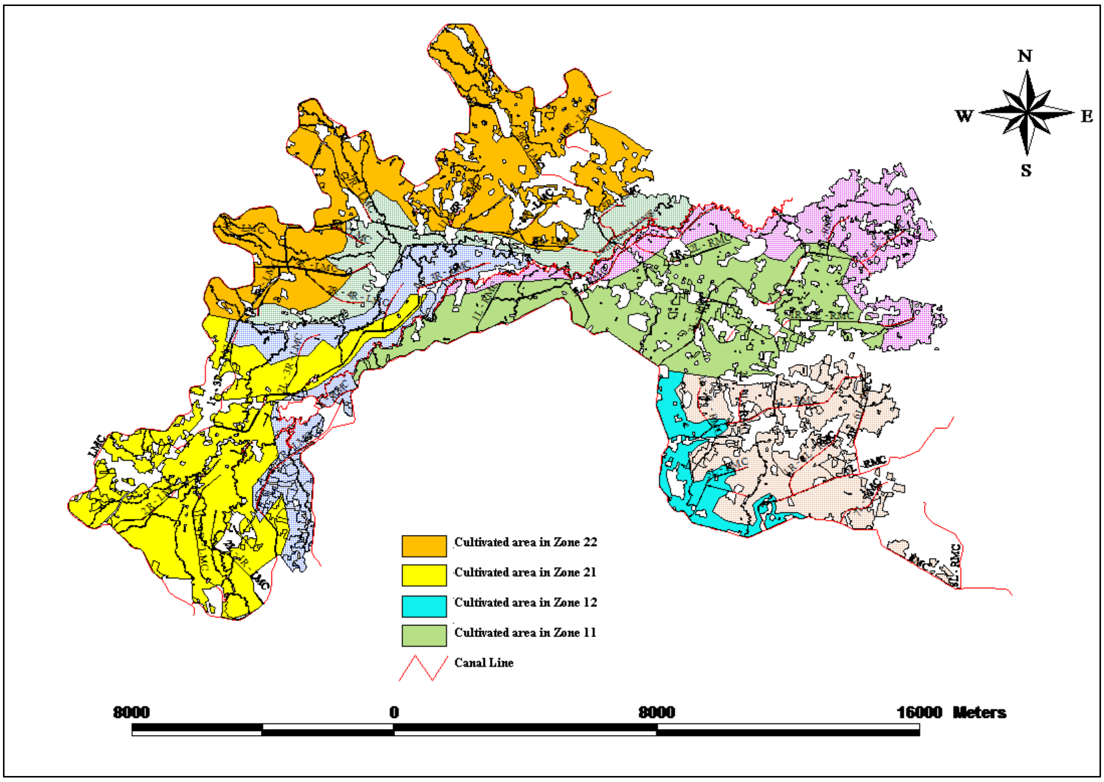


Fig. 6. The estimated area of each zone during dry season

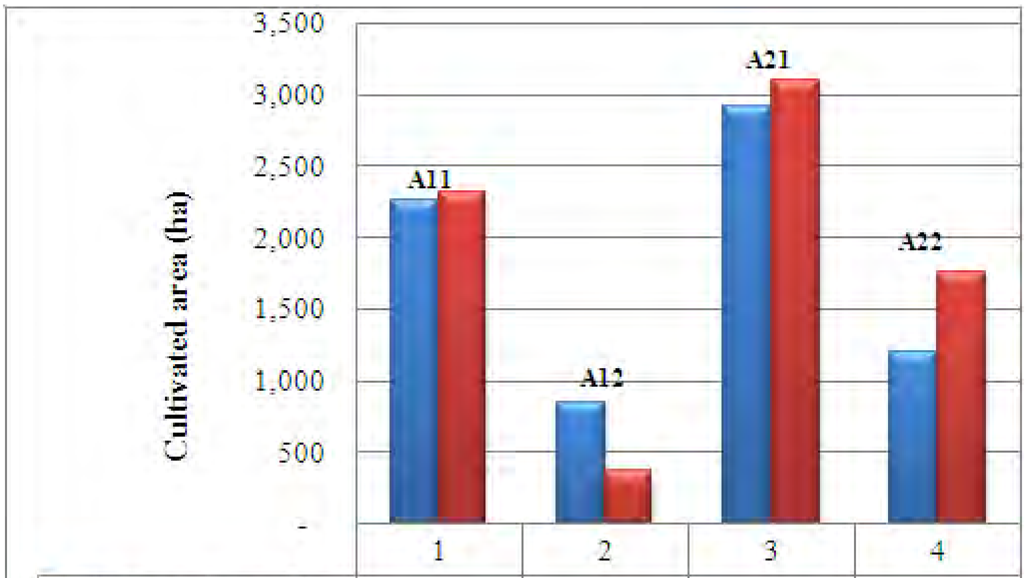
C. Comparison of actual cultivated area and estimated area using graph information

Table 4 shows the actual cultivated area equivalent to paddy and the estimated area from graph using the information in 2011/2012 year for all area zones. They indicate that the estimated areas are close to the actual cultivated area for all zones. The average difference of the results obtained by graph and the actual area in main canal system is 4.53%. Hence, the farmer can use the graph information to plan their cultivation when they know the available water. However, when the water did not divert to canal, they use water from nature canal and suction from the other sources until harvest.

Fig. 7 shows the actual cultivated area of year 2011/2012 and the estimated area of the second alternative plan for each zone. It present that the area of both method are close together.

TABLE IV
The actual cultivated area equivalent to paddy and the estimated area from graph

Year	Area Zone	The equivalent cultivated area as compared with paddy (ha)	The estimated cultivated area from graph (ha)	The differences (%)
2011/2012	A11	14,500	14,150	2.47
	A12	2,345	5,320	-55.92
	A21	19,355	18,210	6.29
	A22	10,975	7,450	47.32
Total		47,175	45,130	4.53



	1	2	3	4
Estimated area (the second altemative plan)	2,264	851	2,914	1,192
Actual cultivated area (2011/2012)	2,320	375	3,097	1,756

Fig. 7. The actual cultivated area of 2011/2012 and the estimated area of the second alternative plan

IV. CONCLUSIONS

This study used a LP model to search optimal crop-area planning during dry season of the Huai Luang Irrigation Project. There are 4 types of water requirement in the project such as paddy, farm plants, and vegetable and fish pond. These 2 alternative plans were performed including the first alternative plan is cultivation without share area of each zone. The second alternative plan was cultivation by shared area of each zone that allocated water to all zones by 50% first, then 50% remain will be grown in 4 weeks later. The results found that the the obtained results of the second alternative plan were higher than the results of the first plan. Then, the second plan was selected to create the graph of available water and the estimation of cultivated area zone. The results also, presented that the actual cultivated area equivalent to paddy were closed to the estimated area from graph for all area zones. The farmer can use the graph information to plan their cultivation when they know the available water.

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