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Evaluation of the Overnight Storage Reservoir Utilization for Sugarcane Cultivation

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ABSTRACT

The research was conducted to compare the effectiveness of the irrigation overnight storage utilization with a nearby irrigation canal system of non-existing overnight storage. Performance evaluation was made by using the 3-group indicators, including output, impact, and internal process indicators. It was shown that there were statistically no difference of indicating values between the two systems. In other words, the effectiveness of the overnight storage utilization can not be seen clearly under the similar system management of both systems at present.

Key words: overnight storage, performance evaluation, output indicator, impact indicator, internal process indicator

INTRODUCTION

Uptill now, irrigation and drainage system in Thailand has been developed mainly for rice cultivation. Large-scale irrigation for upland crops is still new and needs more experiences for further development. In accordance with the types of field layout, there are basically two methods of rice irrigation control that are being practiced at present. One of which is a semi-controlled irrigation by which water flows from plot-to-plot. Another method is a direct-controlled irrigation by which each farm plot has a direct access to irrigation and drainage facilities. Semi-controlled irrigation is not applicable for upland crops which requires a close supervision during the time of irrigation. This implies that daytime irrigation is recommended.

There are two main crops, i.e. sugarcane and rice cultivated in the Malaiman project area of the Greater Mae Klong Irrigation Project. Due to its difficulty for night applications of water, limiting irrigation of sugarcane with a 12-hour schedule during daytime only for the entire system would seriously effect to the on-going design and construction of irrigation system. This will require to find an appropriate method of water delivery for the area with mixed cropping of sugarcane and rice. Overhead irrigation is an alternative that night-time irrigation would be possible with no disadvantage to the existing system. However, with the present high costs of energy and low sugar prices, overhead irrigation for sugarcane is not considered to be feasible. It is also not applicable for rice irrigation. Changes in cropping patterns and prices of agricultural commodities may lead to an increased interest of overhead irrigation in the future (ILACO/ Empire M&T, 1980 ; 1984 ; 1985).

Considering several alternates including

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economic implications and operational aspects, a 24-hour supply schedule in combination with a 12-hour irrigation schedule, and storage at lateral canal level was recommended by ILACO/Empire M&T (1985) as the most suitable solution under the present situation

To maximize an effective utilization of the overnight storage, the research was conducted with the two main objectives:

- To evaluate an effectiveness of the utilization of an existing overnight storage irrigation system.

- To compare the operational performances of the existing overnight storage irrigation system with the non-existing overnight storage irrigation system.

MATERIALS AND METHODS

Principles

Performance assessment is a measure to see whether or not the objectives are being achieved. It concerns the identification of performance indicators and variables for evaluation (Oads and McCornick, 1989). Selected performance measures are to focus on a system's own outputs, its impact on its external environment and its internal processes (Small and Svendsen, 1992 ; Malano and Hofwegen, 1999), of which performance indicators in each categories were selected and listed in Table 1 (Rao, 1993 ; Oad and Podmore, 1989 ; IIMI, 1989).

In general, three broad types of performance assessments can be identified and described as follows.

Output measures : This is an assessment of the quantity and quality of the system's final outputs. They must be specified in consistence with the boundaries used in defining the system. The selected output indicators were overall irrigation efficiency, delivery performance ratio, reliability, relative water supply, and storage ratio.

Impact measures : This is an evaluation of the effects of the system's outputs on the larger environments. Impact measures may be focused on outcomes and dispersed effects. The selected impact indicators were designed to evaluate the outcomes of irrigation including yield, and yield ratio.

Process measures : This is an assessment of a systems' internal operations and procedures in the creation of intermediate and final outputs, Therefore, they are important in explaining a systems' outputs and impacts. The selected internal process indicators were manpower number ratio, staff in O&M ratio, accountability of staff ratio, and user's stake in irrigation system.

Methodology

Goals attainment is evaluated by comparing actual system performance with target system performance in the form of a ratio in which the performance variables are expressed by the magnitude of the resource used (Oads and McCornick, 1989; Small and Svendsen, 1992). Procedures to measure its magnitude are described in each step of measurements hereafter.

- Site selection
- Measuring actual and target water delivery
- Determining actual and target storage volume
- Scheduling target and actual period of water delivery
- Interviewing farmers and irrigation personnels
- Surveying crop production

Site selection

Two irrigation canals of the Song-Phi-Nong irrigation operation & maintenance project were choosen for the study, of which 6L-2L lateral canal comprising with 3 overnight storage reservoirs was used for an evaluation of its utilization under the first objective ; and 7L-2L lateral canal of non-existing overnight storage was used to compare the operational performance of both canal systems under the second objective.

Both systems have a similar physical

Table 1 Selected irrigation performance indicators.

Indicators	Equations
1. Overall irrigation efficiency, E_i	$E_i = \frac{\text{Theoretical crop's need}}{\text{Actual water delivery}} \times 100 = \frac{Q_n}{Q_a} \times 100$
2. Delivery performance ratio, DPR	$DPR = \frac{\text{Actual discharge}}{\text{Target discharge}} = \frac{Q_a}{Q_t}$
3. Reliability, $R = P_2 - P_1$	P_1 = % of observed flow not exceeding target flow-10% P_2 = % of observed flow not exceeding target flow + 10%
4. Relative water supply, RWS	$RWS = \frac{\text{Irrigation + Effective Rainfall}}{\text{Evapotranspiration + Seepage + Percolation}} = \frac{I + Re}{ET + S + P}$
5. Storage ratio, S	$S = \frac{\text{Actual storage volume}}{\text{Target storage volume}} = \frac{V_A}{V_T}$
6. Yield ratio, Y	$Y = \frac{\text{Actual yield}}{\text{Target yield}} = \frac{Y_a}{Y_t}$
7. Manpower number ratio, MNR	$MNR = \frac{\text{Total manpower number}}{\text{Water delivery area}} = \frac{MN_t}{Ad}$
8. Staff in O&M ratio, SOM	$SOM = \frac{\text{Actual staff}}{\text{Required staff}} = \frac{S_a}{S_r}$
9. Accountability of staff ratio, AS	$AS = \frac{\text{Actual accountability}}{\text{Required accountability}} = \frac{A_a}{A_r}$
10. User's stake in irrigation system, US	$US = \frac{\text{Active water user organizations}}{\text{Total water user organizations}} = \frac{U_a}{U_t}$

characteristics, i.e. locating nearby each other, no sub-lateral with almost the same length of canal, having the same soil group, and growing sugarcane mostly in both commanded areas.

Measuring actual water delivery

The 6L-2L canal is equipped with the overnight storage reservoirs and is designed for a 12-hour irrigation schedule during daytime only. Therefore, the actual water delivery to the field cannot be determined from the average rate of flow through outlet structures downstream of the reservoirs, since water will be stored at night and is supplied in daytime only. Then , water balancing of overnight storage is applied for the determination of actual water delivery as shown in Figure1.

Water balance of overnight storage is expressed as :

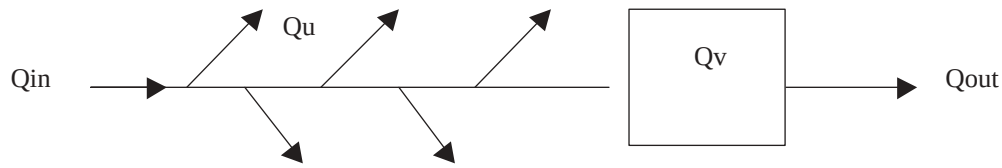

Figure 1 Water balance of overnight storage.

$$Qu = Qin - Qout \pm Qv \quad (1)$$

where :

Qu = the rate of water delivery to field, m^3./sec.

Qin = the rate of inflow, m^3./sec.

Qout = the rate of oulflow, m^3./sec.

Qv = the rate of change of water storage, m^3./sec.

For 7L-2L canal, there is non-existence of the overnight storage and is operated for 24 hours/day. Thus, the rate of water delivery to the field can be determined from the average daily rate of flow through control structures for each canal section. The expression can be written as follow.

$$Qu = Qin - Qout \quad (2)$$

Determining target water delivery

Target water delivery is determined by theoretical crop water need divided by irrigation efficiency, from which theoretical crop water need refers to amount of crop evapotranspiration under the existing cropping pattern minus effective rainfall. The related expressions can be written as follow.

$$I_R = (ET_c + P + L_p) - R_e \quad (3)$$

$$ET_c = k_c * ET_o \quad (4)$$

where :

I_R = the amount of net irrigation requirement, mm./day

ET_c = the amount of crop evapotranspiration, mm./day

P = the amount of deep percolation, mm./day

L_p = the amount of water requirement for land preparation, mm./day

R_e = the amount of effective rainfall, mm./day (with the use of simulation model by Suiadee (1994), and Acres Inter. Ltd. (1979)).

k_c = crop coefficient

ET_o = the amount of potential evapotranspiration, mm./day

Determining actual and target storage volume

Actual storage volume can be determined from the change of storage reservoir volume with the use of rating curve, and is related to the canal discharge as expressed in equation 1). Water storage level is recorded twice daily at 06:00 hr. and 18:00 hr.

Target storage volume is determined from the multiplication of target water delivery and the period of daily supply schedule (12 hrs/day). The expression can be written as follow.

$$V_t = Q_t \times 12 \text{ hr.} \quad (5)$$

where :

V_t = Target storage volume, m^3

Q_t = Target water delivery, m^3/sec.

Scheduling target and actual period of water delivery

Target period of water delivery is determined from cropping schedule for which sugarcane irrigation is required from planting in February till August. Thus, target period is scheduled at 7 months (28 weeks). However, water delivery beyond August still continues within a limited area for other crops such as rice. Continuation for actual period of water delivery will be underway till the weeks of 32^{th} - 34^{th}.

Interviewing farmers and irrigation personnels

Specific variables in some performance indicators are obtainable from interviewing. Some questions need the answers to verify the evaluated values for the comparision of those with and without cases.

With the use of questionnaire, farmers were randomly selected from those who planted virgin and ratoon sugarcane (2 nd. and 3 rd. year) with more or less equal number of farmers for each canal section. The location of plots selected for each canal section were divided into 3 groups, i.e. along or nearby irrigation canal, in between irrigation canal and drain, and along or nearby the drain. Farmers (sugarcane growers) were interviewed by the zonemen.

Irrigation personnels were also interviewed by using questionnaire. They were including 4 zonemen and one Head of operation and maintenance section. Those are working or had been experiencing with the two canal systems of with and without overnight storages.

The results of interview (see Table 3 and 4) were satisfactory in verifying the evaluated values shown in Table 2. They were also described briefly below.

Farmers' responses to questionnaire

In brief, the farmers' responses regarding the supply of irrigation water were found to be adequate (100%), timely (85-81%), satisfactory (73-69%) for the 6L-2L and 7L-2L canals respectively. The practice of irrigation was mainly during the daytime (71-65%) and the remainder was both in day and at night-time (29-35%) for the two systems. The preference of farmers in water

Table 2 Performance evaluation results.

Indicators	Equations	Results	
		6L-2L	7L-2L
1. Output indicators			
1.1 Overall irrigation efficiency, (%)	Ei = (Qn/Qa) 100	42.08	40.76
1.2 Delivery performance ratio	DPR = Qa/Qt	0.95	0.75
1.3 Reliability (%)	R = P2 – P1	10.71	3.57
1.4 Relative water supply	RWS = (I+Re)/ET+S+P	3.01	2.97
1.5 Storage ratio (%)	S = (VA/VT) 100	47.4	-
2. Impact indicators			
2.1 Yield	ton/rai	13.48	12.15
2.2 Yield ratio	Y = Ya/Yt	0.89	0.86
3. Process indicators			
3.1 Manpower number ratio	MNR = MNt / Ad	1:18,000	1:10,000
3.2 Staff in O&M ratio	SOM = Sa / Sr	1:06	1:02
3.3 Accountability of staff ratio	AS = Aa / Ar	0.85	0.80
3.4 User's stake in irrigation system	US = Ua / Ut	0.56	0.71

receivability between the 6L-2L and 7L-2L canals was almost no difference (56-47%), whereas farmers who had no preference were also almost the same percentages (25-32%) These will imply to the evaluated values of output indicators shown in Table 2.

For both systems, farmers irrigated their plant only 5-6 nos./crop for virgin sugarcane, and only 3-4 nos./crop for ratoon sugarcane with an irrigation interval of 15 days for both cases. They

Table 3 Farmers' responses to questionnair.

Question	Percent of farmers	
	6L-2L	7L-2L
1. How often do you receive the advice from irrigation personnel regarding water use?		
❒ Much	9	18
❒ Moderate	38	46
❒ Less	53	36
2. When do you irrigate your field ?		
❒ Daytime	71	65
❒ Night-time	-	-
❒ Both	29	35
3. How do you apply irrigation water to your farm		
❒ By gravity from irrigation ditch	55	31
❒ By pumping from irrigation ditch	45	69
4. Do you receive irrigation water at the time you need?		
❒ Yes	85	81
❒ No	15	19
5. Do you receive irrigation water adequately?		
❒ Yes	100	100
❒ No	-	-
6. How do you compare water receivability of the field between the 6L-2L and 7L-2L canals?		
❒ Better at 6L-2L	56	21
❒ Better at 7L-2L	19	47
❒ Same	25	32
7. Do you satisfy with canal discharge?		
❒ Yes	85	81
❒ No	15	19
8. How do you irrigate your sugarcane?		
❒ No. of irrigation	5-6 nos./yr.	5-6 nos./yr.
- virgin sugarcane	3-4 nos./yr.	3-4 nos./yr
- ratoon sugarcane	15 days	15 days
❒ Irrigation interval	4-6 mos.	4-6 mos.
9. At what plant age that you stop irrigation?		

Table 4 Irrigation personnels' responses to questionnaire.

Question	Percent of personnels	
	6L-2L	7L-2L
1. What kind of structures that were equipped with overnight storage caused difficulty or problem in operation?		(not applicable)
❒ Structure/Problem	Automatic gate : - Gate setting steal by water users. - Children jumping in the stilling basins Baffle distributor : - Gate opening steal by water users. - Cumbersome manual control of structure.	
2. Were the offtakes along the canal that was equipped with overnight storage suitable for use?		(not applicable)
❒ Yes	100	
❒ No		
3. Was the size of each overnight storage capable with the command area of each canal section?		(not applicable)
❒ Yes		
❒ No	75	
- Large		
- Small	25	
4. How do you compare the simplicity of operation between the canals equipped with and without overnight-storage?		
❒ With overnight storage	-	100
❒ Without overnight storage		
5. What are the problems in operation of the canal that was equipped with overnight storage?	5.1) Gate setting steal of automatic gate for fishing and jumping purposes. 5.2) Improper functioning of automatic gate due the the lack of maintenance.	(not applicable)

Table 4 (Continued).

Question	Percent of personnels	
	6L-2L	7L-2L
	5.3) Water scarcity at the tail end when the canal discharge is low.	
6. What are the problems in operation of the canal that was not equipped with overnight storage?	(not applicable)	6.1) Head gate opening steal. 6.2) Too much or too less water at the tail end.
7. How often do you receive training in the operation of overnight storage canal?		(not applicable)
❒ Much	25	
❒ Moderate	50	
❒ Not at all	25	
8. How do you think to increase irrigation efficiency in the overnight storage canal?	8.1) Increasing manpower. 8.2) Farmers training for daytime irrigation. 8.3) Tightening of gate opening steal.	(not applicable)
9. Was the overnight storage functioning properly as to the design?		(not applicable)
❒ Proper	50	
❒ Not proper	50	
10. In which canal that has more request from farmers to assist them in irrigation water		
❒ 6L-2L	-	
❒ 7L-2L		100
11. How do you consider the farmers' cooperation.		
❒ Much		
❒ Moderate	100	100
❒ Less		
12. How do you think to allow farmers to participate in irrigation water delivery?		
❒ Yes	100	100
❒ No		

stopped irrigation when the plant age was about 4-6 months. Irrigation was undertaken by the two means of gravity (55-31%) and pumping (45-69%) from the self-help irrigation ditch since land consolidation work was not yet undertaken.

The responses on a visit and advice of irrigation personnel to farmers were found to be varying from much (9-18%), moderate (38-46%), and less (53-36%) for the 6L-2L and 7L-2L canals respectively.

Irrigation personnels' responses to questionaire

In short, the responses of irrigation personnels to the questionnaire can be grouped into 3 parts regarding the systems and structures, farmers, and irrigation personnels themselves.

The responses regarding the systems and structures were including the problems encountered, the systems' simplicity and services, the designed suitability of the overnight storage reservoir.

For the existing overnight storage system of the 6L-2L canal, the structures that caused difficulty or problems in operation were automatic gate and baffle distributors equipped with the overnight storage. The problems were gate setting steal by water users, children jumping in the stilling basin, cumbersome manual control of the baffle distributors, improper functioning of automatic gate due to the lack of maintenance, water scarcity at the tail end when the canal discharge was low.

For the non-existing overnight storage of the 7L-2L canal, the structure that caused problems in operation was the head gate. The problems were gate opening steal by water users, too much or too less water at the tail end.

In comparision between the two systems, the systems' simplicity for operation was given to the 7L-2L canal (100%). However, the services were required more in the 7L-2L canal (100%) as the system had more requests from farmers to render the assistance in water issues.

The responses regarding the designed suitability of the overnight storage were found to be proper functioning (50 : 50), sizable (75 : 25). The offtakes along the 6L-2L canal were also responded as suitable for use (100%)

For farmers' cooperation, the responses were found to be moderate (100%) in both systems. Similary, farmers' participation should be required in irrigation water delivery (100%) in both systems.

For irrigation personnels themselves, the responses regarding in-service training were found to be much (25%), moderate (50%), not at all (25%). The responses on ways to increase effectiveness of the existing overnight storage system of 6L-2L canal included increasing manpower, farmers training for daytime irrigation, tightening gate opening steal.

Surveying crop production

Surveying sugarcane production was undertaken through the questionnaire for interviewing farmers who owned their farm plots. Surveying was conducted separately for virgin and ratoon sugarcane with more or less equal planted areas for each canal section. The location of plots randomly selected for each canal section were divided into 3 groups, i.e. along or nearby irrigation canal, in between irrigation canal and drain, and along or nearby the drain.

The rusults of surveying showed an average yield of 13.48 and 12.15 tons/rai for 6L-2L and 7L-2L respectively. With the estimated target yield of 15.2 tons/rai for 6L-2L and 14.08 ton/rai for 7L-2L (ILACO/Empire M&T, 1980), yield performance was then calculated at 0.89 and 0.86 for 6L-2L and 7L-2L respectively.

RESULTS AND DISCUSSION

Results

With the comparison of actual and target system performance from those selected performance indicators and variables of 3 groups, the achievement of operational objectives of irrigation system was then evaluated from the

measurement and determination of variables used. The results were summarized as shown in Table 2.

Discussion

1. Effectiveness of system management (Output indicators)

Considering all output indicators (see Table 2), there was no difference for the effectiveness of system management between the 6L-2L and 7L-2L, by which they were and were not equipped with overnight storages respectively. With those indicators, there were statistically no difference of the evaluated values between the two systems, except the reliability. However, they were quite low for both cases. The storage ratio was also low at 47.40%, showing the use of water at night. These can be concluded that the effectiveness of the existing overnight storage was still unclear under the similar system management of both system at present.

2. Impact of system management (Impact indicators)

Briefly, indicating values of impact indicators, including yield and yield ratio were not distinguished between the two systems of 6L-2L and 7L-2L, by which there existed and was non-existed with the overnight storages respectively. The average yield and yield performance of both systems were closed to each other. These will agree with the results of output evaluation and will confirm the questionable effectiveness of the existing overnight storages under the similar system management of both systems at present.

3. Effectiveness of internal process (Process indicators)

The modern system of 6L-2L canal that was equipped with the automatic overnight storages still lacks of man-power (see Table2). Similarly, the 7L-2L canal which is delivering water 24 hr./ day, also has insufficient man-power with a better degree to the 6L-2L canal. The evaluated values of process indicators reflected the effect of the internal operation of a system to outputs (Malano and Hofwegen, 1999), i.e. contributing unpreeminentable performance between the two distinguished systems.

CONCLUSIONS

Performance evaluation of two irrigation systems, existing with and without the overnight storages for sugarcane cultivation by the comparison of 3-group indicators showed that the effectiveness of the existing overnight storages was still unclear under the similar system management of both systems at present.

To be the guidelines for improving the effectiveness of the overnight storages utilization, measures should be undertaken as follows.

1. Provision of farmers' need.
2. Provision of readiness prior to bring in a new technology, e.g. related technical knowledge, well-trained operating staff, and maintenance costs.
3. Provision of definite irrigation scheduling, and monitoring & evaluation plan.
4. Provision of sufficient in-service training for the related personnels and of advise to farmers.
5. Provision of restudy for the effect of overnight storage utilization after the improvement of system management and internal operation process of the system organization.

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