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Evaluation of Water Use in a Rice Double Cropping System in Malaysia

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ABSTRACT. *Irrigated rice all over Asia has been criticized for inefficient water use, but very little information is available to quantify its performance. The quantification or assessment of the inefficiency will give the farmers, managers or schemes and policy makers to come up with remedial measures. In this work, the Besut rice irrigation scheme, located in the Terengganu State of Malaysia was characterized, and its water use (WU) efficiency assessed. The daily rainfall for 48 years and river flows for 45 years were analyzed to identify water excess or shortage throughout the rice-growing season. During the November-January period, 45% of the total annual rains fall. The irrigation water supply could be reduced in the main season (November-April) because of higher rainfall occurrence. Low monthly river flows of 10.5 m^3/s and 10.9 m^3/s were observed for the Besut barrage and 2.3 m^3/s and 2.4 m^3/s for the Angga barrage in the months of July and August respectively, characterizing the driest months. The off-season (May-October) crop suffered from water problems during vegetative and reproductive stages because of water shortage in the river. The relative water supply values have been classified into five categories based on results on the indices on irrigation performance. The average water productivity was 0.31 kg/m^3 and 0.25 kg/m^3 during the main season and off-season respectively. Two WU indices, water productivity (WPI) and adequacy (AI), ranked the performance of the blocks and identified those having problems in water allocation and utilization. These indices revealed that the blocks using more water performed poorly in terms of water productivity. These indices could be used to rectify uneven distribution of water in the scheme.*

INTRODUCTION

More than 90% of the world's rice is produced and consumed in Asia. More than 80% of the freshwater resources developed in Asia, are used for irrigation. Of this, more than 90% of the total irrigation water is used for rice production. The available water for irrigation, however, is becoming increasingly scarce due to decreasing resources and quality, and increased competition from non-agricultural water users. For food security, it is essential to "produce more rice with less water" (Cabangon *et al.*, 2002). Appropriate water management for rice therefore of becomes important and the effective and efficient use of water can never be more emphasized; especially in free-water-to-irrigator systems, as practiced widely in Asia.

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In many irrigation projects around the world, water use (WU) efficiencies are below expected levels (Clemmens and Dedrick, 1992; 1994). Low efficiency can be attributed to factors such as inadequate irrigation structures, poor on-farm management and/or insufficient water availability. Levin and Coward Jr. (1989) suggested that a system that is considered fair by most farmers is more efficient than the one designed by Water Authorities on the basis of productivity and efficiency but is considered unfair by the farmers. Any irrigation distribution system, which practices equity in water allocation and distribution, will have uniformity in the cropped area and crop vigor along the distribution system. However, if there is a large and consistent difference in the cropped area and vigor between the head and the tail ends of the distributaries, the distribution system cannot be considered to be practicing equity.

In many countries around the world, there is an increasing concern about the performance of irrigation schemes because many schemes are not producing the expected returns, or they are suffering from water supply restriction and/or water quality problems. Although good on-farm irrigation is crucial for good performance of any scheme, the bottleneck is often in the irrigation delivery system. A number of on-farm irrigation performance indices have been defined (Merriam and Keller, 1978; Burt *et al.*, 1997). These indices quantify water management, and serve to identify problematic areas within irrigated schemes. However, they do not provide any information on the reasons for the observed level of performance or provide guidance on how to improve it. Addressing performance problems is complex since improvement in farm water management must be viewed in the context of overall farm management. A Management Improvement Program (MIP) (Dedrick *et al.*, 1993; 2000) is an effective way to identify both the strengths and the weaknesses of irrigated agriculture. Management of the irrigation scheme implies optimum crop production and efficient use of water resources. Performance assessment is considered to be one of the most critical elements for improving irrigation management. Therefore, the objective of this paper is to quantify the current water use in terms of productivity and adequacy of a selected irrigated rice system.

MATERIALS AND METHODS

Study site

The study was carried-out at the Besut Irrigation Scheme, located in the northeastern corner of Peninsular Malaysia in the State of Terengganu. The scheme consists of 2 sub-schemes, namely, Angga Barrage sub-scheme and Besut Barrage sub-scheme. These sub-schemes are further divided into 4 compartments, with one compartment in the Angga sub-scheme (Compartment 2) and three compartments in the Besut sub-scheme (Compartment 1, 3 and 4). The scheme has 39 irrigation blocks or water user's groups. There are two sources of water supply for the scheme namely the Sungai Angga and Sungai Besut Rivers. Compartments 1, 3 and 4 (totaling 4,017 ha) receive irrigation supply by gravity from the Besut barrage, while compartment 2 (1,147 ha) receives irrigation supply also by gravity from the Angga barrage. The irrigation systems of both areas are interconnected, giving a total area of 5,164 ha. The main objective of the scheme is to enhance rice production by double cropping and improved farming, to achieve set self-sufficiency level in rice. The major constraints confronting the irrigation scheme in 0.the fulfillment of its prescribed goals are: (a) water management problems, and (b) insufficiency of water in the canal system to meet the demand of the entire irrigable area.

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Effective rainfall

Effective rainfall (ER) is the portion of rainfall that contributes to the water requirements of growing rice in the field. The rainfall is only effective when it is stored and used by the rice crop. Estimation of the effective rainfall is complicated. The effective rainfall for the irrigated condition can be determined by the drainage model of the International Rice Research Institute (IRRI, 1977) as follows:

$$ER_j = \left(1 - \frac{DR_j}{RF_j + IR_j}\right) * RF_j \qquad [1]$$

Where RF_j is the rainfall during the period j, IR_j the irrigation requirement during the period j, DR_j the drainage requirement from the rice field during period j, ER_j the effective rainfall during the period j.

In the Besut Irrigation Scheme, where water is continuously supplied, excess water is drained whenever it exceeds a maximum allowable level (D_d). When standing water depth (WD_j) exceeds the maximum allowable water depth in the field, drainage is required as:

$$DR_j = WD_j - D_d, \text{ if } WD_j > D_d \qquad [2]$$

For efficient water use, rainfall should be fully utilized and unnecessary percolation eliminated. Three rain gauging stations were chosen for this study considering their spatial representativeness as well as the availability of adequate data for the study. Daily rainfall data for a period of 48 years (1951–1998) were obtained from the Data Information Section of the Department of Irrigation and Drainage (DID), Malaysia.

River Flows

The rice fields are irrigated through river barrages and a network of main, secondary and tertiary canals. For system operation and alternative water resource development, monthly and yearly records of river flows are required to take decisions on water release through barrages. Staff gauge readings for Sungai Angga at Angga Barrage and Sungai Besut at Jerteh, and the daily records of water level were obtained from the DID, Malaysia. River flow records are available for the Besut and Angga barrages for a period of 45 years (1946-1990). Monthly river flows were calculated using the Log Pearson Type III distribution as follows:

$$\log QT_r = avg\ (\log Q) + [K(T_r, C_s)] * \sigma \log Q \qquad [3]$$

where T_r is the return period, K the frequency factor, C_s the skewness coefficient, σ the variance and Q the discharge.

Irrigation performance indices

The present irrigation system was evaluated using three performance indices under different categories. The first two indices (adequacy and equity) describe the water delivery system, while the last index (agricultural productivity) describes the irrigated agriculture system.

The adequacy indicator answers the question – to what extent the quantity of water provided is sufficient for growth needs of the crops (Abernethy, 1989). The relative water supply (RWS), defined by Levin (1982), describes the adequacy of water supply. The RWS is computed by the following expression:

$$RWS = \frac{IS + ER}{IRG} \quad [4]$$

Where IS is the irrigation water supply, ER the effective rainfall and IRG the gross irrigation requirement. The gross irrigation requirement is computed as the net irrigation requirement (NIR) divided by irrigation efficiency, to account for losses during conveyance, distribution and application. Irrigation efficiency value was taken as 45% which is given in published report (JICA, 1998) for the study area. Net irrigation requirement (NIR) is computed using the following expression:

$$NIR = ET_o * K_c + SP - ER \quad [5]$$

Where; ET_0 is the reference crop evapotranspiration (mm/d), K_c the crop coefficient and SP the combined seepage and percolation (mm/d).

Evapotranspiration rate (ET_0) was not measured at the study site, but was estimated from meteorological data. The crop coefficient (K_c) values published for the study area (Chan and Cheong, 2001) were used. The amount of irrigation water supplied to each irrigation block was collected during the field data collection.

Agricultural production performance indicators include cropping intensity, ratio of area planted and area harvested, annual yield, productivity of land and productivity of water (Rao, 1993). In this study, an attempt has been made to estimate water productivity index using observed crop yield data. Water productivity index can be expressed as:

$$WPI = \frac{CY}{WS} \quad [6]$$

Where CY the crop yield and WS is the amount of water supplied. The basic assumptions in water productivity index are: (i) a uniform distribution of rainfall over each discrete unit; (ii) homogeneous soils within each unit; (iii) same variety is grown in the scheme; (iv) management techniques that give farmers timely access to water are same.

RESULTS AND DISCUSSION

Rainfall and river flow

Generally, crop production during the main season is influenced by the rainfall distribution and the crop duration. The long-term rainfall records indicate that maximum rainfall occurs in September, October, November, December and January with monthly mean rainfall values of 260, 262, 504, 650 and 190 mm, respectively. Almost half of the annual rainfall falls during this period. Effective rainfall is based on historical rainfall data, averaged expected rainfall was taken to estimate weekly effective rainfall in this study. Effective rainfall was found to be 68% during the pre-saturation period and 54% during the growth stage. The weekly effective rainfall for the Besut rice irrigation scheme is shown in Figure 1 and it clearly indicates that the irrigation supply can be reduced in the main season because of more rainfall occurrence.

The scheme comprises two irrigation units, which receives water from the Angga and Besut barrages. The monthly river flow patterns in the scheme throughout the growing season are presented in Table 1. The peak river flows were found to be 153.0 m^3/s and 94.5 m^3/s for the Besut barrage and 20.2 m^3/s and 12.5 m^3/s for the Angga barrage in the month of December and January, respectively. The lowest monthly river flows were found to be 10.5 m^3/s and 10.9 m^3/s for the Besut barrage and 2.3 m^3/s and 2.4 m^3/s for the Angga barrage in the months of July and August, respectively. The lowest values of rainfall are observed for July and August indicating the driest months of the year. The traditional off-season period follows with land preparation scheduled from 5 May to 20 May. The off-season crop normally suffers water problem during the vegetative and reproductive growth stages because of low river flow.

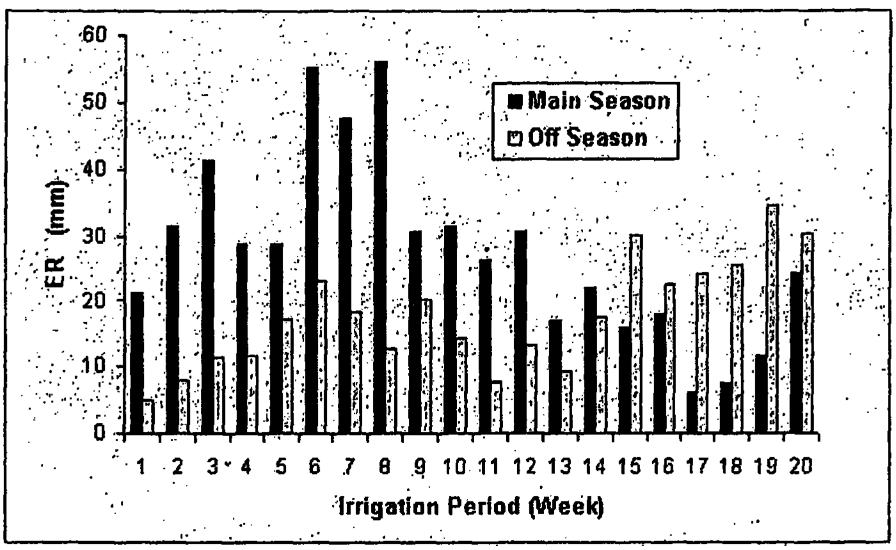

Fig. 1. **Weekly effective rainfall for both main season and off-season**

Irrigation performance

The adequacy of water supply to various blocks was assessed by estimating RWS for each block during the cropping season. The block-wise RWS values for the main season are shown in Figure 2. Values of RWS ranged from 0.6 to 3.3. Out of the 39 irrigation blocks, 29 had RWS values more than 1.5. This indicated that farmers in the canal command areas generally tend to over-irrigate. The irrigation blocks have been classified into five categories, *i.e.* excessive water surplus (RWS > 3.0), high water surplus (2.0 < RWS < 3.0), moderate water surplus (1.5 < RWS < 2.0), adequate water (1.0 < RWS < 1.5), and water deficit (0.6 < RWS < 1.0). There were 2 blocks in which the water surplus was more than three times the crop water requirement, and 15 blocks received more than twice the crop water requirement. Three blocks, which are located towards the tail end of the irrigation scheme, received water between 0.6 and 1.0 of the crop requirement. Blocks located towards the head of the main and secondary canals mostly received higher amounts of water. On the other hand, 8 blocks received more than twice the water demand during the off-season (Figure 3).

The water productivity index by the crop was computed from Equation (6). The WPI was estimated for each irrigation block separately, as blocks are different in size. The productivity of water ranged from 0.15 to 0.48 kg/m^3. The irrigation blocks of various compartments have been classified into four groups (< 0.2, 0.2 – 0.3, 0.3 – 0.4 and > 0.4 kg/m^3) based on water use efficiency (Figure 4). Out of the 39 irrigation blocks, five had low WPI values (< 0.2 kg/m^3) and eight had high WPI values (> 0.4 kg/m^3). The average water productivity was 0.31 kg/m^3 in the main season. In the off-season (Figure 5), seven blocks had low WPI values (< 0.2 kg/m^3) and three had high WPI values (>0.4 kg/m^3). The average water productivity was 0.25 kg/m^3 during the off-season. A comparison between the spatial distribution of irrigation blocks in Figures 2 to 5 showed the blocks which received high volumes of water produced lower yields than the areas which received less water. This showed that over-irrigation does not increase productivity proportionately to the increment of water.

CONCLUSIONS

In this study, the lowest monthly river flows were found to be 10.5 m^3/s and 10.9 m^3/s for the Besut River and 2.3 m^3/s and 2.4 m^3/s for the Angga River in the months of July and August, respectively. Therefore, off-season (May-October) crop suffers water problem during the vegetative and reproductive stages because of low flow. The irrigation performance of various blocks was assessed by estimating RWS during the main season and off-season. The RWS values in the main season were found to be from 0.6 to 3.3. Based on RWS values, it was observed that blocks located towards the head of the main and secondary canals mostly received higher amounts of water. The present performance analysis showed that WU-based performance indicators could identify the problem blocks in the scheme. On the other hand, the average water productivity was found to be 0.31 kg/m^3 and 0.25 kg/m^3 during the main season, and off-season respectively. It has also been found that a greater application of water does not result in higher crop yield. Therefore, not only an accurate amount of irrigation water at the appropriate time is beneficial for crop growth but also a key to improve the irrigation efficiency. Thus, regular water use assessment could provide irrigation authority with the means of managing the irrigation scheme efficiently by changing the pattern of water supply.

Table 1. Probable flow of the Besut and Angga River

Return Period (Year)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Besut River Flow (m^3/s)						
20	25.0	6.5	5.7	7.5	8.1	8.3	7.1	7.7	14.8	11.6	17.6	37.5
10	28.6	8.5	7.5	8.9	9.5	9.9	9.0	9.7	17.0	14.5	23.1	43.1
5*	**34.7**	**11.9**	**12.2**	**13.1**	**11.5**	**12.2**	**10.5**	**10.9**	**21.3**	**19.4**	**23.1**	**55.3**
4	38.6	14.0	12.4	12.0	12.6	13.4	14.0	15.1	24.1	22.2	32.0	65.1
3	44.3	17.1	15.2	13.6	14.1	15.3	16.8	18.0	28.3	26.5	47.8	80.2
2	53.8	22.7	20.5	16.1	16.7	18.3	21.7	23.2	35.7	34.2	64.7	107.7
						Angga River Flow (m^3/s)						
20	6.4	1.2	0.9	1.5	1.6	1.7	1.3	1.5	3.5	2.6	4.3	10.0
10	7.5	1.7	1.4	1.8	2.0	2.1	1.9	2.1	4.2	3.5	5.9	11.6
5*	**9.2**	**2.7**	**2.8**	**3.0**	**2.6**	**2.7**	**2.3**	**2.4**	**5.0**	**4.9**	**8.6**	**15.1**
4	10.3	3.3	2.8	2.7	2.9	3.1	3.3	3.6	6.2	5.6	10.4	17.9
3	11.9	4.2	3.6	3.1	3.3	3.7	4.1	4.4	7.4	6.9	13.0	22.2
2	14.7	5.8	5.2	3.9	4.1	4.5	5.5	5.9	9.5	9.0	17.8	30.1

* Values taken in this study follow Log Pearson Type III.

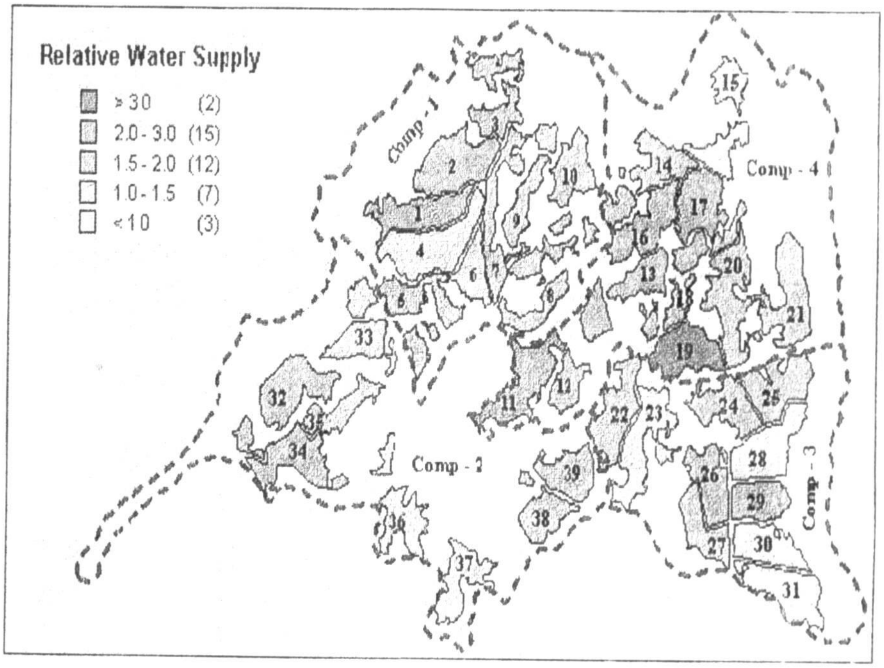

Fig. 2. Block-wise relative water supply of the main season

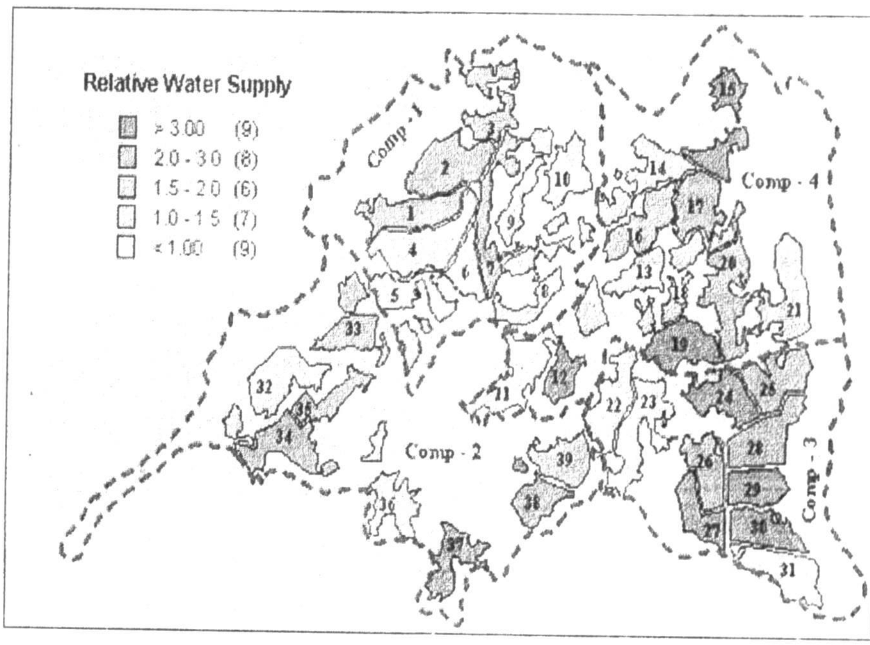

Fig. 3. Block-wise relative water supply of the off season

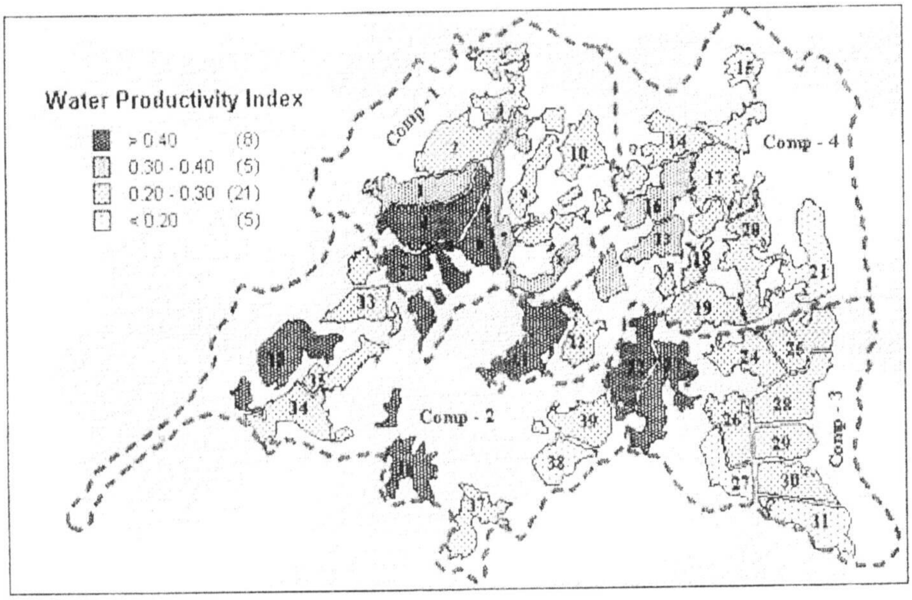

Fig. 4. Block-wise water productivity of the main season

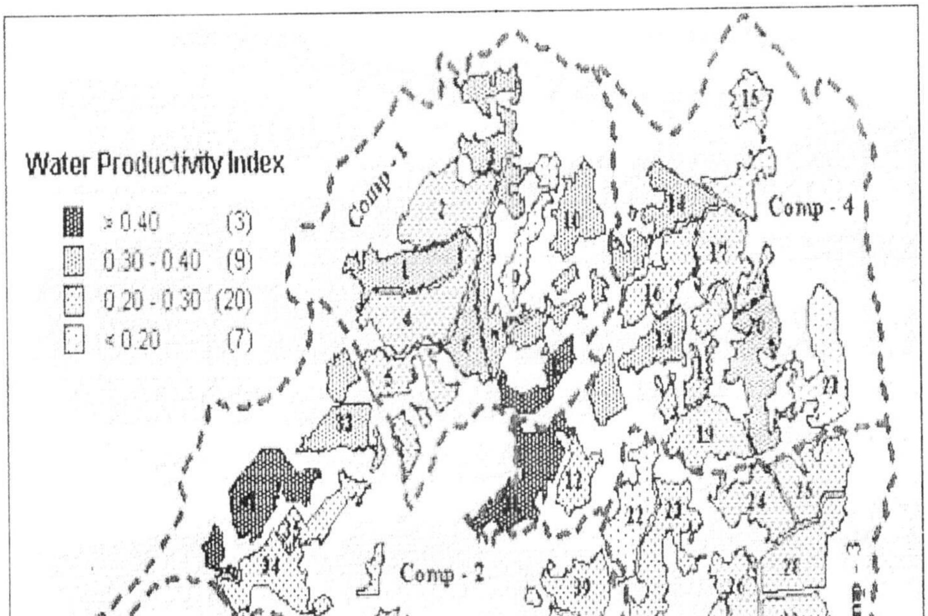

Fig. 5. Block-wise water productivity of the off-season

REFERENCES

Abernethy, C.L. (1989). Indicators of the performance of irrigation distribution systems. In: Proceedings of the Symposium on the Performance Evaluation of Irrigation Systems. International Irrigation Management Institute (IIMI), Colombo, 23 November 1989. pp. 26 - 32.

Burt, C.M., Clemmens, A.J., Strelkoff, T.S., Solomon, K.H., Bliesner, R.D., Hardy, L.A., Howell, T.A. and Eisenhauer, D.E. (1997). Irrigation performance measures: efficiency and uniformity. J. Irrigation and Drainage Engineering 123 (6): 423 - 442.

Cabangon, R.J., Tuong, T.P. and Abdullah, N.B. (2002). Comparing water input and water productivity of transplanted and direct-seeded rice production systems. J. Agricultural Water Management 57: 11 - 31.

Chan, C.S. and Cheong, A.W. (2001). Seasonal water effects on crop evapotranspiration and rice yield. J. Tropical Agriculture and Food Science 29 (1): 77 - 92.

Clemmens, A.J. and Dedrick, R. (1992). Identifying factors that influence farm water use. In: Technical Papers, vol. II. Conferencia Regional Panamericana, Mazatla'n, Sinaloa, Me'xico, 10 pp.

Clemmens, A.J. and Dedrick, A.R. (1994). Irrigation techniques and evaluations. In: Tanji, K.K., Yaron, B. (Eds.), Advances in Series in Agricultural Sciences, Springer, Berlin, pp. 64 - 103.

Dedrick, A.R., Clyma, W., Tenney, O.L., Clemmens, A.J., Gibson, R.D., Levine, D.B., Replogle, J.A., Rish, S.A., Ware, R.E. and Wilson, P.N. (1993). A demonstration irrigation management improvement program. In: Proceedings of the 15th Congress on ICID, The Hague, The Netherlands, pp. 95 - 104.

Dedrick, A.R., Bautista, E., Clyma, W., Levine, D.B. and Rish, S.A. (2000). The management improvement program (MIP): a process for improving the performance of irrigated agriculture. Irrigation Drainage System 14: 5 - 39.

IRRI (1977). Annual report 1997, International Rice Research Institute, Los Banos, Phillippines.

JICA (1998). The study on modernization of irrigation water management system in the granary area of Peninsular Malaysia. Draft Final Report, Volume-II, Annexes, Japan International Cooperation Agency.Levin, G. (1982). Relative water supply: An explanatory variable for irrigation systems. Technical Report No. 6, Cornell University, Ithaca, New York, USA.

Levin, G. and Coward Jr., E.W. (1989). Equity considerations in the modernization of irrigation systems. ODI-IIMI Irrigation Management Network paper 89/2b, International Irrigation Management Institute, Colombo, Sri Lanka.

Merriam, J.L. and Keller, J. (1978). Farm Irrigation System Evaluation: A guide for management. Utah State University, Logan, UT, 271 pp.

Rao, P.S. (1993). Review of selected literature on indicators of irrigation performance. IIMI, Colombo, Sri Lanka, 75 pp.