WATER ALLOCATION MODELING FOR IN BESUT RICE IRRIGATION SCHEME IN MALAYSIA

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ABSTRACT: *This study analyzed the ways for water distribution in a rice growing area during the pre-saturation and normal irrigation supply periods. The analyses were conducted using field data collected at the Besut Irrigation Scheme located in the state of Terengganu, Malaysia. The scheme comprised of two sub-schemes, which were further subdivided into compartments and blocks. Based on field water requirements during the pre-saturation and normal irrigation supply periods and available flows at the intake structures, canal simulation was performed using the CanalMan model. Results have shown that the pre-saturation should not be done continuously unless flow rate is at least 9.00 m^3/sec at Besut intake gate. If the respective flow rate falls below this value, then the pre-saturation should be done in two stages. However, when the flow rate is between 5.00 and 5.60 m^3/sec at Besut intake gate, the pre-saturation is recommended to be carried out over three stages. During the normal irrigation supply period, flow rate of 5.00 m^3/sec for the Besut intake gate, is to be maintained for the whole irrigation scheme.*

1.0 INTRODUCTION

Malaysia is a rice growing country and, with the complication in rice cultivation practices, emphasis has been placed on the efficient farm water management. Rice has been cultivated in the coastal plains in Malaysia for a long time. In the past, rice cultivation was carried out once in a year using local traditional systems. Double cropping of rice was fully implemented in 1988. The efficient utilization of water resources needs information, such as annual effective rainfall, runoff, consumptive use, and water release policy etc., for the application of the computer modeling system in water management.

Water shortages have become more frequent and farmers often face deficiencies in water deliveries, resulting in reduced yields and incomes. Poor management of available water for irrigation, both at system and farm level, has led to a range of problems and further aggravated water availability, reducing the benefits of irrigation investments. More efficient irrigation management must be introduced if more food needs to be produced at the same condition as water is diverted to other uses. Increased efficiency in the use of water is essential for future food security in Asia where rice production has to be increased by 70% by the year 2025 (Hossain, 1997; Tuong, 1999). It is clear that irrigation service today has to take on multiple objectives and aim at specific targets. Irrigation performance should not be measured by just how well water is delivered and managed but whether the final output justifies the continued service of irrigation. A saving of 5% in irrigation water can meet 15% of water demand for domestic and industrial sector (Teh, 1998). The challenge is therefore to save water from agriculture sector for eventual transfer to the domestic and industrial sectors. The primary objective of this study is to investigate methods of effective allocation of available water resources in order to achieve higher water productivity.

2.0 METHODOLOGY

2.1 Study area

The study area, the Besut Irrigation Scheme, is located in the northeastern corner of Peninsular Malaysia in the state of Terengganu. The general rice field irrigation scheme is shown in Figure 1. The scheme consists of 2 sub-schemes, namely Angga barrage sub-scheme and Besut barrage sub-Scheme. These sub-schemes are further sub-divided into 4 compartments: one compartment in the Angga sub-scheme (Compartment 2) and three compartments in the Besut sub-scheme (Compartment 1, 3, 4). The Besut barrage sub-scheme is selected in this study. Compartments 1, 3 and 4 (totaling 4017 ha) receive water supply by gravity irrigation from Besut River System. The Besut sub-scheme area is further divided into 31 irrigation blocks or water user's group. The main canals convey water downstream and divert to secondary and tertiary canals through discharge measuring off-take structures. Check gates are provided along in both main secondary canals to increase the water level in the canals, when necessary. Irrigation infrastructure of this sub-scheme has been provided for double cropping rice. Water supply adequacy is sensitive to the water levels at the Besut Barrage. When the water level of Besut River is +13.9 m (above mean sea level), then the whole sub-scheme is irrigated continuously. On the other hand, when the water levels fall below the above desired level, the scheme is irrigated in a rotational basis. When drought occurs, the drains become supplementary sources of water. There are five recycling pumping locations from where water is pumped into the irrigation canals. There are two planting seasons each year, the main season and the off-season. At present, water management problems are the most important constraints confronting the sub-scheme in achieving its goal.

2.2 Overview of CanalMan model

The CanalMan (Canal Management Software) model was used for performing hydraulic simulations of unsteady flow in branching canal networks. The *CanalMan* model was developed by Utah State University, Logan, Utah, USA (Merkley, 1997). This model is based on partial differential equations (the Saint-Venant equations for one-dimensional flow) that allow the flow rate and water level to be computed numerically as functions of space and time. The advantage of the model is that it computes the flow rate and water level simultaneously, so that the model more closely approximates the actual unsteady non-uniform nature of water flow in a canal. The model is highly interactive and includes integrated data editing capabilities, with numerous options for canal system configuration, hydraulic simulations, and obtaining results. Canal networks are built interactively by inserting and arranging nodes graphically on-screen in a system layout window, where nodes represent locations of flow control structures and canal bifurcations. The CanalMan implicitly solves an integrated form of the Saint-Venant equations of continuity and motion (Strelkoff, 1969) for one-dimensional unsteady open-channel flow. The model incorporates turnout structures and in line structures. Simulations can be started by filling an empty canal system, continuing a previous simulation or from a specified steady or unsteady flow condition.

2.3 Crop water demand

Double cropping of rice is an activity that uses plenty of water. In rice irrigation, more than half of the water supplied is used for pre-saturation; i.e. to pre-saturate and inundate fields before planting the crop. Reducing the pre-saturation period may lead to water saving. For that reason, during pre-saturation period the system should deliver at the maximum capacity in order to reach all the fields as fast as possible for planting without delay. The water requirement for pre-saturation is theoretically 150 – 200 mm, but can be as high as 650 –900 mm when its duration is prolonged, i.e. 24 – 48 days (De Datta, 1981; Bhuiyan et al., 1995). The water required during pre-saturation can be calculated as follows:

$$LP = S + D + E + SP \qquad (1)$$

where, LP is water requirement during land preparation, S is saturation water, D is initial depth of flooding, E is evaporation rate and SP is percolation loss.

Irrigation supply for a field block through a gate can be estimated according to field water requirements. In normal irrigation supply period, water requirement can be calculated using formula (JICA, 1998) shown below.

$$DWR = \frac{\left(ET_o * K_c + SP - ERF\right)}{E_s} \qquad (2)$$

where, DWR is diversion water requirement, ET_o is reference evapotranspiration, K_c is crop coefficient, ERF is effective rainfall, E_s is overall irrigation efficiency. The value of E_s, which includes irrigation efficiency and conveyance efficiency along the secondary canals, was found to be 45 % (JICA, 1998). For soil saturation depth, the Department of Irrigation and Drainage (DID), Malaysia standard value of 150 mm was applied. For standing water depth, 100 mm was used for the pre-saturation period. Percolation value was obtained from operation and maintenance manuals collected from DID local office.

Several types and forms of evapotranspiration (ET) equations are available, each of which provides estimates of reference ET that differ from others (Wright, 1982; Allen et al., 1989; Jensen et al., 1990), but the FAO Penman-Monteith (Allen et al., 1998) is now recommended as the standard method for the definition and computation of the reference evapotranspiration. Md Hazrat et al. (2000) also recommended the same method after applying it to the Muda Irrigation Scheme in northwest Malaysia. The crop water requirement was then determined from the product of reference evapotranspiration and crop coefficient. The crop coefficient values for the study area were used (Chan and Cheong, 2001) and shown in Figure 2. The weather data of the study area were collected for a period of 18 years (1985-2002).

2.4 Canal flow simulation

Canal bed width, side slope, canal length, gate structure and specification, water depth, and full supply level during the pre-saturation period data need to be supplied to the CanalMan database files as input parameters in order to run the model. These data were obtained from the Department of Irrigation and Drainage, Malaysia. Canal flow simulation was performed for the pre-saturation and normal irrigation supply periods. Different flow rates for the Besut intake gate was used in canal simulation process because flow rates change during the main season and off-season. Canal simulation was started with the designed flow capacity because of data availability and then with gradual decreased flow capacity approach for the Besut intake gate. In each simulation process, simulated flow values were compared with design canal flow values to obtain water allocation area. Moreover, canal gate openings were adjusted whenever the simulation flow was higher than the demand. All simulation results were analyzed and possible water allocation areas were identified for pre-saturation period in phases and also repeated for the irrigation supply period for the whole scheme.

3.0 RESULTS AND DISCUSSION

3.1 Water requirements

This study revealed that 250 mm of water was needed for pre-saturation in both the main season and off-season. The mean monthly general weather conditions and water requirements for each month of the year are shown in Figure 3. The crop evapotranspiration was found to be 4.20 and 3.99 mm/day for off-season and main season crop respectively. Crop water requirements were higher during the off-season than the main season, mainly due to prevailing weather conditions. The average seasonal consumptive use of water for rice cultivation was 795 mm, out of which

572 mm (72%) was accounted for ET and 223 mm (28%) for percolation. On the other hand, the average seasonal water supply was 1045 mm of which 732 mm (70%) was supplied by irrigation and 313 mm (30%) by rainfall. It may be pointed out that water requirement was especially high for pre-saturation compared to supplementary supply in both the main and off-seasons.

3.2 Water allocation

Water level reduction along the main canal would cause difficulty in irrigation water supply. During the first two weeks of the simulated period, the requirement for rice cultivation comprises only the water requirement for land preparation. During this period, various flow rates for the Besut intake gate was used in the canal simulation process. Simulation results were compared with the canal design capacity and were found to be satisfactory.

During pre-saturation period, it was found that the total scheme area could not be inundated continuously in a single operation unless flow rate was 9.00 m^3/sec at Besut intake gate. It was also noted that if the flow rate falls below this value, the pre-saturation should be done in two stages. Accordingly, the areas recommended for receiving water are identified and presented in Table 1. Phase I area is supplied first for pre-saturation time of 14 days at 2.10 l/s/ha. After 14 days, the same rate is supplied in Phase II area. But, if the flow rate is between 5.00 and 5.60 m^3/sec in Besut intake gate then pre-saturation should be done over three phases. In this case, each phase is supplied for pre-saturation time of 21 days at 1.38 l/s/ha. However, when the flow rate falls below 5.00 m^3/sec at Besut intake gate, the pre-saturation inundation should be carried out using recycling pumps. In this case, drains would be utilized as supplementary sources of water, which is pumped up to irrigation canals by five recycling pumps.

After the pre-saturation period, from the fifth week onwards, the irrigation water supply period commences for the next 100 days. During this normal irrigation supply period, 5.00 m^3/sec flow rate for Besut intake gate must be maintained throughout the entire period. Should available flows fall below the expected values stated above, then the simulation process can be repeated to identify optimal areas for irrigation and also areas where it may be best to leave alone in view of inadequate flows available.

4.0 CONCLUSIONS

Depending on water availability, pre-saturation can be done in one continuous stretch for all the compartments or over different phases as suggested by the simulation. During the irrigation period, should water resources in the river system is deemed inadequate, the hydraulic simulation can be pursued to identify the units and compartments those are best for irrigation given that not all units can be supplied due to lack of water. The canal simulation results therefore can have major implications in relation to future management programs directed toward more decision-making and water efficient rice culture. The use of CanalMan model to simulate irrigation canals as a means of improving water allocation in rice double cropping systems through proper gate settings and establishing the extent of choice irrigated areas is therefore recommended.

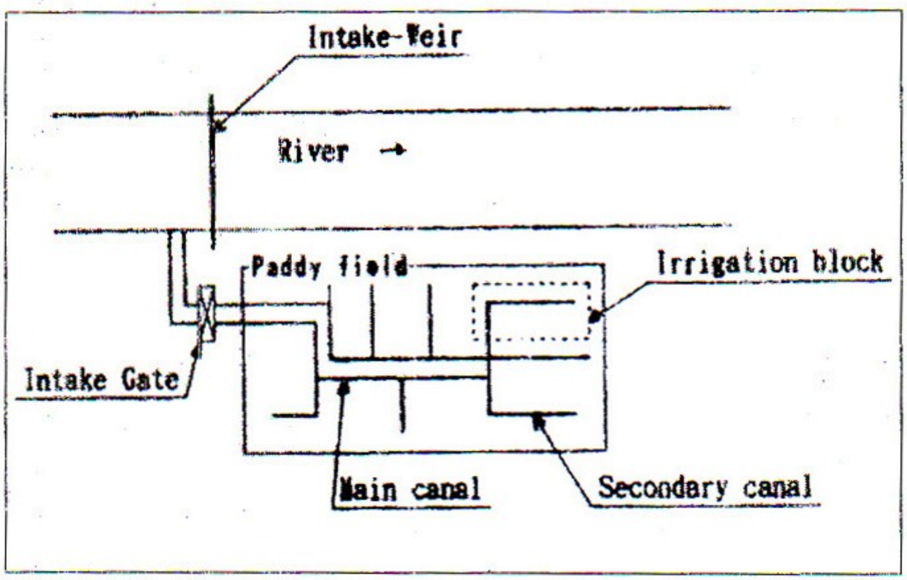

Figure 1. Rice field irrigation scheme of study area

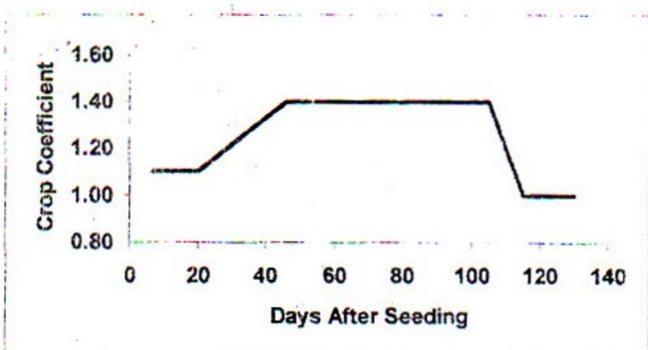

Figure 2. Suggested crop coefficient (K_c) values for rice (MR84 variety)

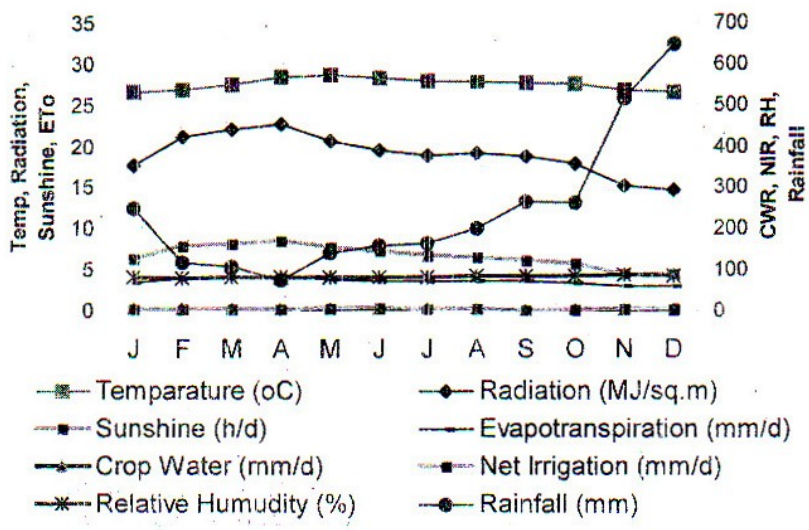

Figure 3. General mean monthly weather conditions for the study area

Table 1. Water allocation area during pre-saturation period derived from water demand and water availability

Intake Gate Flow (m^3/sec)	Irrigable Area (KPA* Unit)		
	Phase-I Area	Phase-II Area	Phase-III Area
> = 9.00	C – 1 (KPA - All); C – 3 (KPA - All); C – 4 (KPA - All);	-----	---
8.20 – 8.90	C – 1 (KPA – All); C – 4 (KPA – All); C – 3 (KPA – 22 – 25);	C – 3 (KPA – 26 – 31);	---
7.20 – 8.10	C – 1 (KPA – All); C – 4 (KPA – 11 – 20); C – 3 (KPA – 22 – 25);	C – 4 (KPA – 21); C – 3 (KPA – 26 – 31);	---
6.20 – 7.10	C – 1 (KPA – All); C – 4 (KPA – All);	C – 3 (KPA – All);	---
5.60 – 6.10	C – 4 (KPA – All); C – 3 (KPA – 22 – 25);	C – 1 (KPA – All); C – 3 (KPA – 26 – 31);	---
5.00 – 5.50	C – 4 (KPA – 11- 20); C – 3 (KPA – 22 – 23);	C – 1 (KPA – All);	C – 4 (KPA – 21); C – 3 (KPA – 24 – 31);
< 5.00	Start pumping for irrigation		

*KPA- Kumpulan Pengguna Air [local Name; i.e. irrigation water user's group] All denotes all KPA units, C denotes compartment, KPA- 22 – 25 denotes from unit KPA 22 to unit KPA 25 etc.

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