WATER BALANCE FOR RICE DOUBLE CROPPING IN THE MUDA AREA, MALAYSIA

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ABSTRACT

Water balance has been studied in a 761 ha irrigation block in the Muda area, in fields characterized by an extremely flat topography with a gradient of 1/10,000 to 1/5,000, heavy clayey soil and long plot-to-plot irrigation (1.6 km as the standard). Water consumption amounted to 3,267 mm in total for two seasons, although it was originally designed for 2,193 mm. The increased water consumption was ascribed to the prolonged inundation period and increase in daily water consumption including evapotranspiration, seepage and percolation.

Irrigation accounted for 56% of the water supply and precipitation for 44%. However precipitation still plays an important role in the presaturation in spite of the higher percentage of irrigation due to the low irrigation efficiency, i.e. only one fourth of the precipitation for the presaturation as the infrastructure is not sufficiently developed under the current field conditions.

Due to the tight water balance, Muda agriculture is facing a water shortage problem, resulting in unstable rice production. In order to improve this situation, the inundation period in the main field should be shortened through the construction of tertiary canals and farm roads at a density of approximately 25 m/ha which would enable each farm unit to gain direct access to the canal and road.

Introduction

The ACRBD4 irrigation block is one of the 100 blocks in the whole Muda area. Its configuration is almost rectangular, i.e. 1.5 km wide on the East-West side and 5 km long on the North-South side. It is considered that the topography and field infrastructure of the block are representative of those of the Muda area. The topography is extremely flat and 80% of the area is located at an elevation ranging from 2.4 m to 2.8 m. The microtopography is complex, as shown in Fig. 1.

Arrangement of the field infrastructure is quite sparse. The terminal irrigation canal, named ACRBD4, is located on the longer side to the East and the drainage canal, named ACRBDR5, on the longer side to the West. Farm roads 3 m wide which are paved with 10 cm thick lateritic soil run along the irrigation and drainage canals. There are few field ditches and roads between the irrigation and the drainage canals, so that for the irrigation supply and transportation field ridges across 20 to 40 lots over a distance of 2.5 km are used.

The Muda area belongs to the tropical monsoon zone. Its annual precipitation is about 2,100 mm, with two peaks observed in May and October (approximately 250 to 300 mm per month) within the rainy season which takes place during the period from April to November. When single cropping was practiced before 1970, the cropping season extended from August to January which is referred to as 2nd season crop under the present double cropping system. The 1st season crop was introduced into the period from February to July according to the Muda I project executed in the 1st Malaysian Plan from 1966 to 1970 to develop the existing primary agricultural infrastructure.

In this paper, the term "flooding period" refers to the period required to complete inundation in a certain area, and "presaturation period" to the inundation period before transplanting (Fig. 2).

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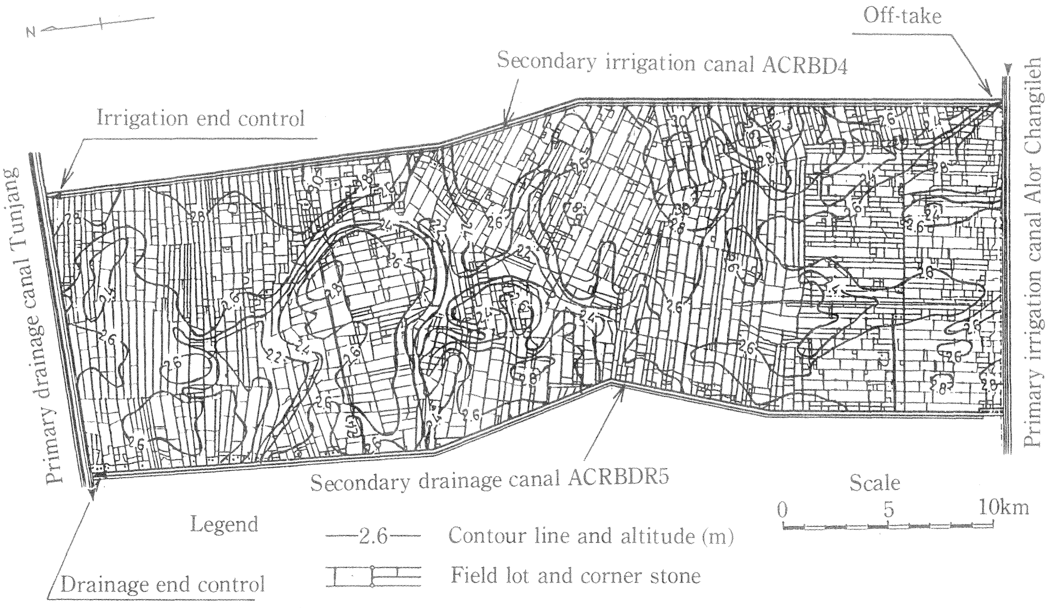

Fig. 1 Lot arrangement and topography in ACRBD4 irrigation block.

Water balance in the ACRBD4 irrigation block

The relationship between the various water balance components in paddy fields can be expressed by the following formula.

$$IR + RF = ET + PS + VS$$

Where IR : Irrigation supply
RF : Rainfall
ET : Evaporation and transpiration
PS : Percolation and seepage including artificially drained water
VS : Variation in the amount of stored water in fields including soil water

Each component was determined by the following methods. The irrigation supply was recorded by automatic water gauges located at the off-take of the secondary canal ACRBD4. The rainfall was measured by a rain gauge set in the block. The evapotranspiration was calculated by the ratio of evapotranspiration to pan evaporation, i.e. 1.21, which was measured by using a 120 cm diameter pan. The variation of the amount of stored water was calculated from the flooding water depth or underground water level observed at 40 monitoring points distributed in the block. As it is difficult to measure the amount of percolation and seepage (PS) directly in the block, this parameter was calculated from the values of the components of the water balance in the above formula.

Data on the water balance in the ACRBD4 irrigation block from 1979 to 1981 are shown in Table 1. The presaturation period in the table was determined from the beginning of the irrigation supply to the time when transplanting had been completed in 50% of the area. The paddy growth period extended from the time when transplanting had been completed in 50% of the area to 20 days before harvesting had been completed in 90% of the area, because inundation conditions need to be maintained up to 10 days before harvesting, so that the irrigation supply can be interrupted 20 days before harvesting.

Table 1 Water balance in ACRBD4 irrigation block

Parameters / Season	Duration	Supply IR	Supply RF	Consumption VS	Consumption ET	Consumption PS	Total	Designed value	Ratio
Observed value	(days)								
1st season crop									
Presaturation period	74	604	393	170	384	443	997	353	2.82
Paddy growth period	105	341	561	-30	581	351	902	765	1.18
Sub-total	179	945	954	140	965	794	1,899	1,118	1.70
2nd season crop									
Presaturation period	54	294	286	43	242	295	580	351	1.65
Paddy growth period	98	597	191	-114	733	169	788	724	1.09
Sub-total	152	891	477	-71	975	464	1,368	1,075	1.27
Total	331	1,836	1,431	69	1,940	1,258	3,267	2,193	
Designed value (total)		967	1,299	-	-	-	2,226	-	

Average for three years from 1979 to 1981.
The designed values are quoted from the "Report on reappraisal of the Muda River Project", p. 7-9, DID, Malaysia, 1964.
Ratio: ratio of the observed value to the designed value.

The total water consumption was 3,267 mm, which is 47% higher than the designed amount. The increase in the water consumption was remarkable, particularly in the presaturation periods, i.e. 997 mm for the 1st season crop and 580 mm for the 2nd season crop or 182% and 65% more than the designed amount, respectively, although the paddy growth period was only 18% and 9% higher than the designed target for the 1st season crop and the 2nd season crop, respectively.

Discussion

The results of the water balance study show that the water shortage problem in the Muda area was caused by the increase in water consumption, especially in the presaturation period of the 1st season crop for which the contribution of irrigation supply is largest in a year. It is considered that the problem is aggravated by the following factors:

1 Prolonged presaturation period before transplanting,
2 Low irrigation efficiency and
3 Delayed and prolonged cropping schedule.

1 Prolonged presaturation period before transplanting

The cropping schedule practiced in the ACRBD4 irrigation block was analysed in conjunction with the water balance study (Fig. 1), in order to investigate the origin of the water shortage problem which is a cause of concern for the Muda farmers. By tracing the line corresponding to the period when 50% of the farm operations (Fig. 2) had been completed, the standard cropping schedule in a lot within the block could be obtained as shown in Table 2. Based on the table it is evident that the presaturation period of the 1st season crop before transplanting was too long, taking 57 days, although two weeks would have been sufficient for land preparation only.

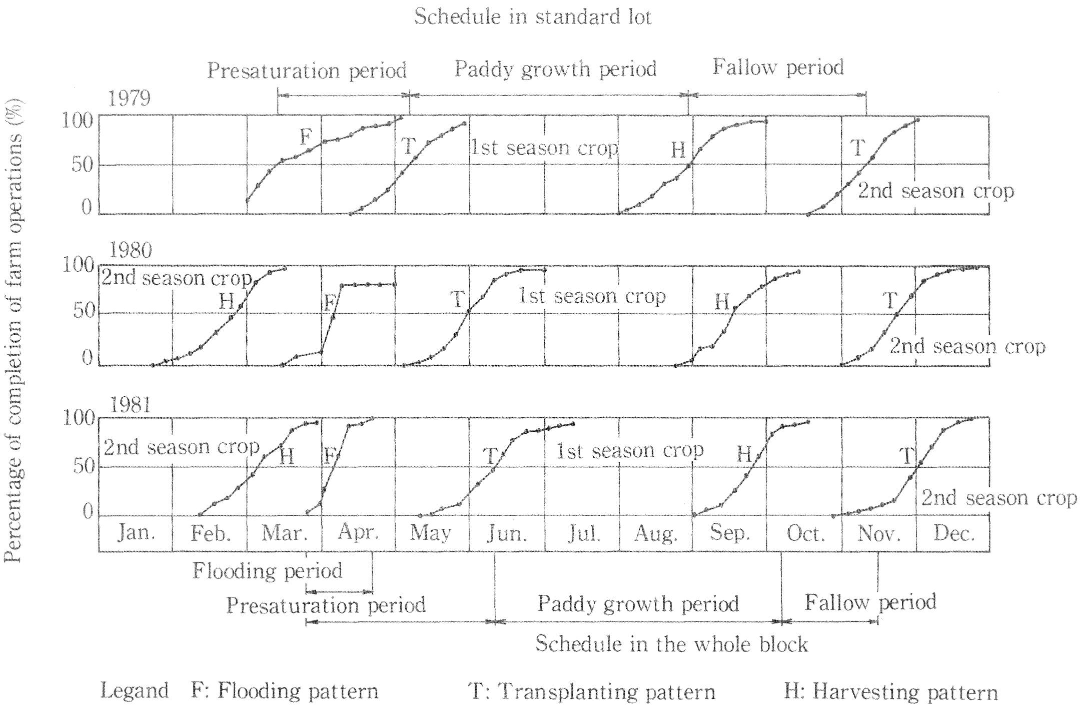

Fig. 2 Cropping schedule in ACRBD4 irrigation block.

Table 2 Standard cropping schedule in the ACRBD4 irrigation block (1979 to 1981)

	Presaturation period	Paddy growth period	Fallow period
1st season crop	Mar. 28 - May 24 (57)	May 25 - Sep. 13 (112)	Sep. 14 - Nov. 16 (66)
2nd season crop		Nov. 17 - Mar. 2 (106)	Mar. 3 - May 24 (86)

Refer to Fig. 2. ( ) indicates duration in days.
Presaturation period: from the time when 50% of the area was flooded until the time when transplanting was completed in 50% of the area.
The paddy growth period covers the time from transplanting to harvesting.
The fallow period includes the presaturation period.

The prolonged presaturation period can be ascribed to the fact that due to the inadequacy of the equipment of the irrigation system, it is difficult to distribute water separately to the nursery beds and main fields. As a result, the main fields are submerged together with the nursery beds which account for only 4% of the area.

It appears that if communal nursery beds could be set up near the secondary canal the presaturation period in the main fields before transplanting could be shortened. However, the lack of farm roads would make it difficult to transport the seedlings to the main fields. As a result, the nursery beds are scattered over the block, and the duration of the presaturation period of the main fields is prolonged to nearly 2 months, although the presaturation period required for land preparation is about 2 weeks.

In order to shorten the inundation period before transplanting, it is important to build a larger number of irrigation canals and farm roads at a proper density, so as to supply water separately to the nursery beds and the main fields and to set up communal nursery beds near the secondary canal. In the ACRBD4 irrigation block, a distance of 330 m on an average would be the proper spacing between an irrigation canal and a drainage canal.

In considering that the average size of a lot is 330 m long and 62 m wide and that 68% of the lots are managed by one farmer and 19% by two farmers, it appears that at least 80% of the farm units can gain a direct access to a canal and a farm road, if the field facilities are set along the narrow side of the lots. Under such conditions water could be supplied separately to the nursery beds, main fields and communal nursery beds, and also the presaturation period could be shortened and the water consumption reduced. When the presaturation period is shortened by 42 days, from 57 days to 15 days, more than 400 mm of water consumption can be cut, as the daily water consumption is approximately 11 mm (Table 1: (384+443) mm/74 days = 11.2 mm/day).

2 Low irrigation efficiency

There were striking changes in the flooding patterns among the three years from 1979 to 1981 as shown in Fig. 2. As will be mentioned later the more abundant the rainfall, the shorter the presaturation period, that is, compared with the high efficiency of rainfall which reaches paddy fields evenly and directly, the efficiency of irrigation supply in which water is conveyed horizontally over a long distance of 1.5 km without canal is very low.

The flooding patterns of the 1st season crop during the three year period are illustrated in Fig. 3 to 5, together with data on the water supply. In 1979, the irrigation started earlier than in the other years, resulting in a limited contribution of rainfall to the water supply. The figure shows that the irrigation was adequate for only 60% of the blocks. Thereafter, flooding proceeded gradually during each rainfall. The flooding period lasted 53 days and of the 827 mm of water supplied, 736 mm originated from irrigation and 91 mm from rainfall, to attain a 90% level of flooding (Fig. 3).

The flooding pattern in 1981 was in sharp contrast to that in 1979. In this year, the onset of irrigation was delayed as the amount of water stored in the dam was insufficient. At the time when the irrigation began on March 28, the rainy season had already started. Due to the abundant rainfall, the flooding was satisfactory and it took only 15 days for 90% of the area to be flooded with a total water supply of 335 mm, of which 152 mm originated from irrigation and 182 mm from rainfall (Fig. 5).

In 1980, the irrigation began on March 28 as in 1981. The flooding area which reached 80% within 13 days due to heavy rain (65 mm) on April 8 remained at the same level in spite of further irrigation supply but due to the lower amount of precipitation (Fig. 4).

The same findings apply to the flooding pattern of the whole Muda area observed by MADA from 1979 to 1982 (Table 3). Table 3 indicates the amount of water supplied during the period when 10 to 90% of the area was flooded.

The flooding period ranged between 5 and 10 weeks, although the average daily water supply was almost the same in the 4 years, amounting to around 10 mm/day, while the contribution of rainfall to the total water supply varied. The relation between the flooding period and water supply in Table 3 can be expressed by the following multiple regression equation.

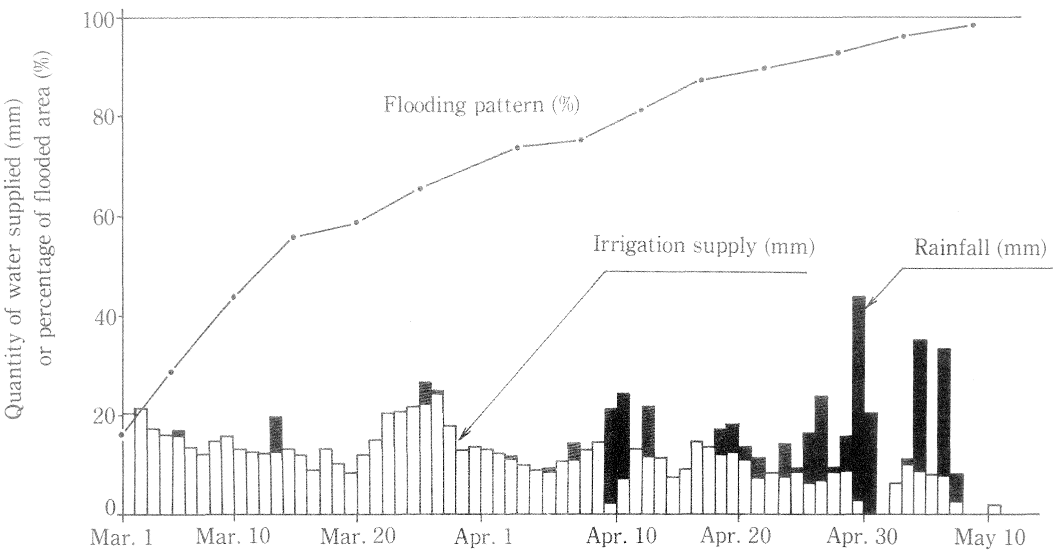

Fig. 3 Flooding pattern and water supply for 1st season crop 1979, ACRBD4 I.B.

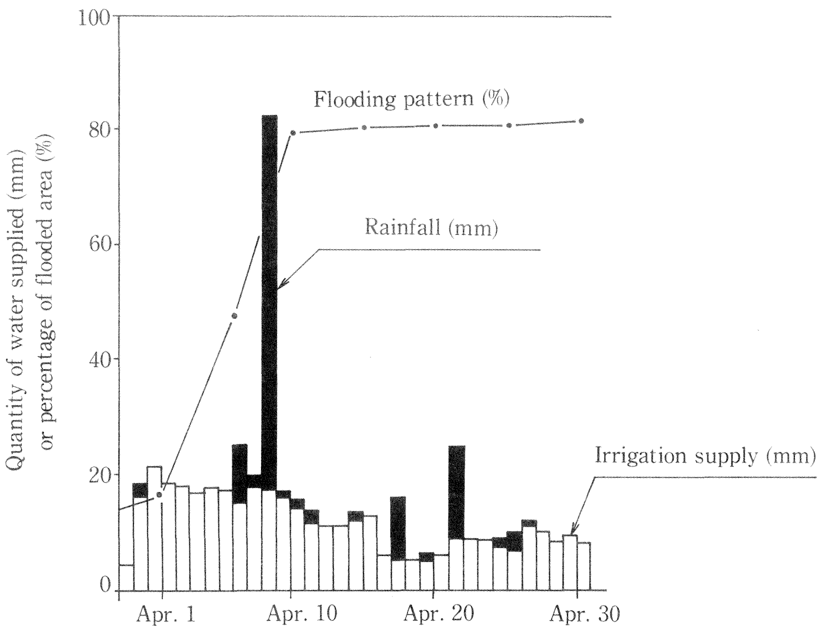

Fig. 4 Flooding pattern and water supply for 1st season crop, 1980, ACRBD4 I.B.

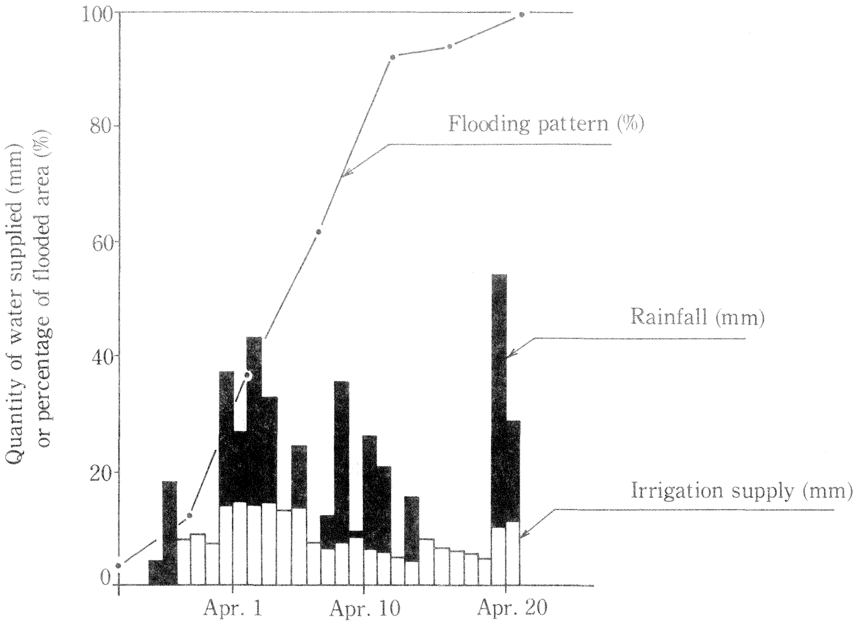

Fig. 5 Flooding pattern and water supply for 1st season crop, 1981, ACRBD4 I.B.

Table 3 Relationship between flooding period and water supply in the whole Muda area (1st season crop)

	1979	1980	1981	1982
Flooding period (weeks)	10	9	8	5
Water supply				
Rainfall (mm/day)	3.1	4.9	6.3	8.8
Irrigation water (mm/day)	7.6	4.1	4.0	1.7
Total (mm/day)	10.7	9.0	10.3	10.5

Note: Flooding period: period during which 10 to 90% of the area is flooded.
Rainfall and irrigation water: average within the flooding period.
Processed from data observed by MADA.

$$P = 16.02 - 1.16\ R + 0.2 \qquad (r = 0.987)$$

Where P : Flooding period (weeks)
R : Average rainfall during the flooding period (mm/day)
I : Average irrigation supply during the period (mm/day)

It was observed that the value of the multiple regression coefficient of the irrigation supply was only one quarter of that of the rainfall. This result suggests that the efficiency of the irrigation supply is only one quarter of that of rainfall in the case of the flooding pattern under the present field conditions in which the canal density is 10 m/ha. This low value may be ascribed to the difficulty in conveying irrigation water due to the lack of on-farm water distribution system.

The low irrigation efficiency resulted in a high water loss, i.e. the loss associated with percolation and seepage amounted to 3.8 mm/day on the average (Table 1: 1.285 mm/331 day), instead of 1.5 mm/day as initially designed.

3 Delayed and prolonged cropping schedule

It was originally considered that most of the water demand for the 2nd season crop would be met with rainfall. However, the irrigation supply exceeded the rainfall in the ACRBD4 irrigation block, i.e. 597 mm of irrigation supply vs 191 mm of rainfall during the paddy growth period (Table 1). This situation was attributed to the fact that the 2nd season crop started when the dry season was already well advanced (Table 2). As a result, the level of evapotranspiration was higher, the river flow and amount of rainfall were lower and most of the water stored in the dam was released, leading to a serious water shortage for the 1st season crop. Consequently the cropping schedule was delayed due to the combination of the following factors.

(1) The water shortage delayed the onset of the 1st season cropping so as to utilize effectively rainfall in the rainy season which starts in April.
(2) The onset of the farm operations which was delayed due to the inadequate field infrastructure resulted in a prolonged presaturation period and fallow period (Table 2).
(3) The use of varieties requiring a long maturity period of approximately 140 days prolonged the paddy growth period, although early-maturing varieties were available in the region.

It seems that the recycling of drainage water, most of which directly flows down to the sea presently, would alleviate significantly the water shortage problem especially in the presaturation period of the 1st season crop when the most critical water shortage occurs and when 56% of the total water supply is lost by percolation and seepage (Table 1). The flat topography of the Muda area makes it difficult to reuse drainage water by gravity, and also accounts for the low irrigation efficiency and the water shortage problem.

The construction of an on-farm canal and farm road network which would allow for individual farm operations in each farm unit or intentionally staggered farm operations among farm units within a farm block may enable to shorten the schedule. The introduction of short term varieties would also be effective.

Further studies should involve the following aspects:

(1) Adjustment of the water balance under field conditions with a canal density of 25 m/ha, and control of the loss of water which is likely to increase with the increase in the canal density.
(2) Development of a method for recycling the drainage water in relation to the quantity and timing of available water.
(3) Adjustment of the water demand for direct seeding culture which has rapidly expanded in the Muda area in recent years.
(4) Development of methods for the operation and maintenance of newly constructed in-field facilities, as well as organization of farmers into water use associations.

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