TARC Report

Water Balance in Low and Flat Paddy Land —A Case Study in the Muda Irrigation Project Area, Malaysia—

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Introduction

The Muda Irrigation Project area composed of paddy lands of 100,000 ha is the biggest rice production area in Malaysia. After the completion of the Muda I irrigation development scheme implemented from 1966 to 1970, the area has been installed with irrigation and drainage systems at a level of 10 m per ha in canal density, and double cropping of rice has been introduced.

However, the area has still been facing some problems. The major problem lies in the inadequate networks of irrigation and drainage canals, density of which had remained at a level of 10 m per ha. This low canal density has been causing a delay of irrigation water distribution and also an increase of irrigation loss during the presaturation period for flooding the paddy fields. Consequently, the cropping schedule of the whole area has been disturbed by the water shortage problem. Too flat topography with a land slope of approximately 1 to 10,000 is another factor aggravating the situation.

With an objective to solve these problems the Muda II project was launched to develop field infrastructure on a fifteen year plan started in 1976. In order to provide technical information pertaining to the above problems a joint research program is being in progress betwen Muda Agriculture Development Authority (MADA) and Tropical Agriculture Research Center (TARC). As a part of this research program the author studied water balance in the ACRBD4 irrigation block, a pilot research area selected out of about 100 irrigation blocks in the area, with a purpose to clarify the present irrigation situation before the completion of the Muda II project. The study was done in the off season 1979.

Experimental area

The pilot research area, named ACRBD4 irrigation block, is 5 km long and 1.5 km wide. It has an area of 762 ha including 731 ha of paddy fields. The terminal irrigation canal, named ACRBD4, runs along one of the long side and the terminal drain, named ACRBDR5, along the other side. The drain is 1.5 km apart from the canal, lacking further systematic canal and drain networks in-between. Accordingly, irrigation water is distributed by means of plot-to-plot irrigation for the distance of 1.5 km. The altitude of the field surface ranges between 2.0 to 3.0 m above the sea level. The constraint to water management in the field is the intricate micro-topography as shown in Fig. 1.

The paddy fields in the pilot area consist of 1,100 lots which are bounded by ridges. The concerned farmers amount to 400 families; the average farm size is 1.8 ha per family.

Cropping season

Fig. 2 shows presaturation, transplanting and harvesting patterns in the pilot research
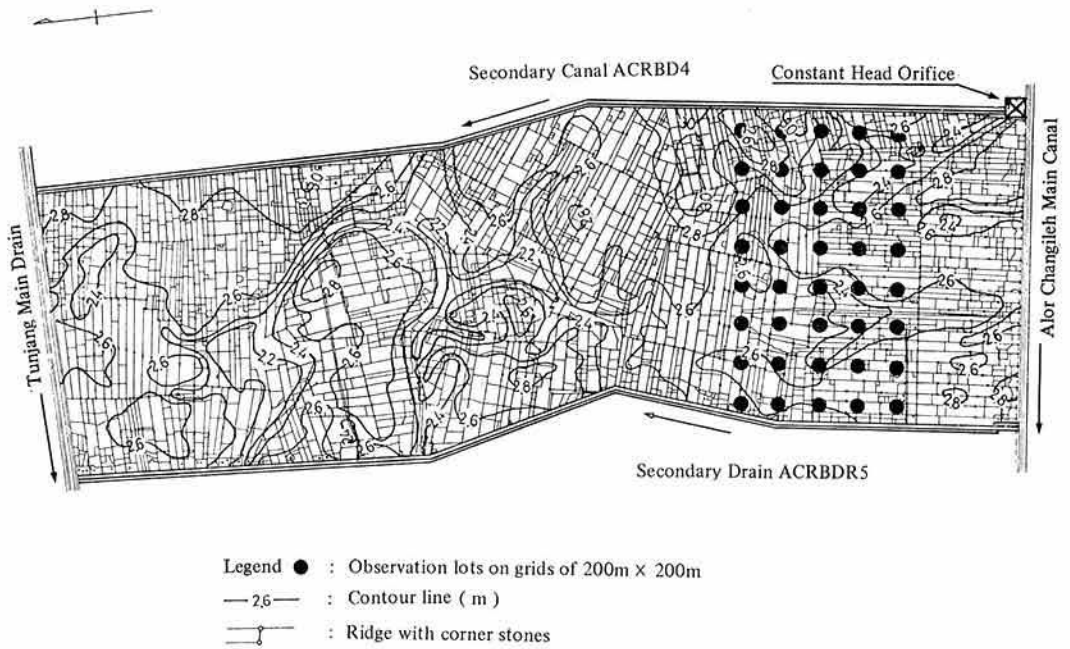
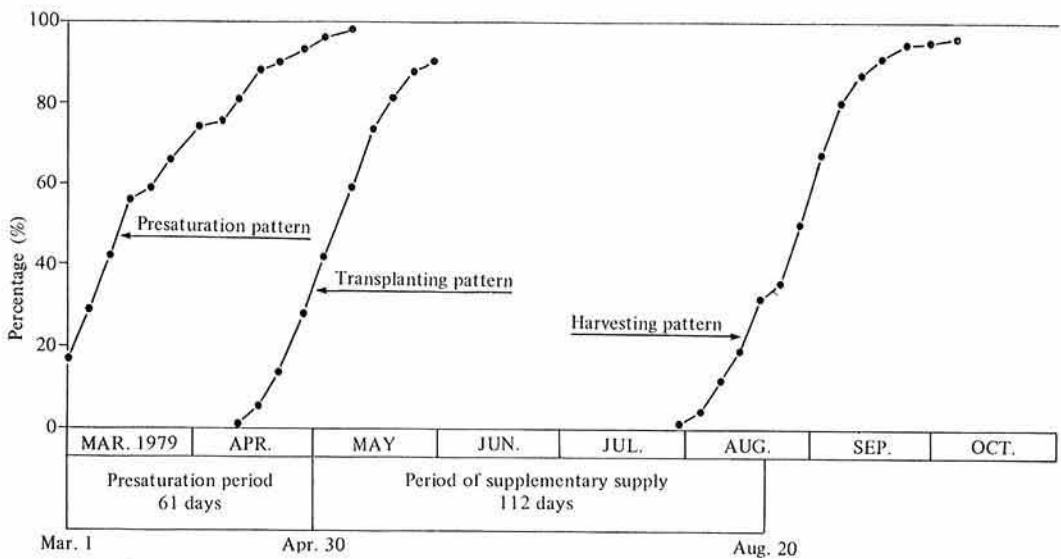Fig. 1.   General Plan of ACRBD4 Irrigation Block

Fig. 2.   Farm operation patterns of the 1979 off season
Observed in 731 ha of paddy fields in ACRBD4 irrigation block, Muda area.

area in the off season 1979. It was found that the presaturation period lasted for 61 days from 1st March when the presaturation supply commenced for the area to 30th April when about 95% of the area was presaturated. The period of the supplementary supply* was from 1st May to 20th August, assuming that water supply is not required in the period of 30 days before harvesting. The duration of water supply was 112 days accordingly. The water balance in the 731 ha of paddy fields was analyzed for the total period of 173 days.

Elements of water balance

1) Irrigation supply

The irrigation supply was measured at the constant head orifice of ACRBD4, in which the head loss and opening of the orifice were recorded by three water gauges. The irrigation supply was divided into two factors, controlled supply from the reservoires and uncontrolled supply from natural river flow, according to the proportion of the two factors at the main headworks.

2) Precipitation

The precipitation was observed in two stations located in the east and west side of the area.

3) Pan-evaporation (EP)

Pan-evaporation (EP) was utilized to estimate evaporation from soil surface before flooding by using ES/EP ratio, already known by the author's previous study in the Muda area. Evapo-transpiration (ET) was actually measured and ET/EP was determined in one field. This ET/EP ratio was employed to estimate ET on other fields with staggering stages of plant growth by using EP values measured. EP was observed by a round shaped and black painted evaporation pan with a diameter of 120 cm, which was in-

stalled on the west side of the area.

4) Evapo-transpiration (ET) and evaporation (E) in paddy field

ET was observed by using 60 cm×60 cm ET-pan set in the paddy field with four hills of rice plants inside. A small water gauge was installed on the pan to record the ET. Evaporation from water surface (E) in paddy field was observed by an E pan which consists of two 60 cm×20 cm pans, one float chamber and one water gauge. The pan was put between hills in the paddy field.

The EP, ET and E observed in the field during the experimental period were summarized in Table 1. ET of 751 mm was observed for the whole growing period of 128 days. It was 21% more than the EP of the same period. A value of 1.56 was the maximum ratio of ET to EP which occurred in the maximum tillering stage. The average ratio of 1.21 was very close to the value reported earlier by Sugimoto[1].

5) Underground water level and flooding depth

These were obtained by manual measurements in 40 observation lots which were distributed on 200 m×200 m grids in paddy field of 150 ha in the experimental area as shown in Fig. 1. It was presumed that the 40 lots could represent the whole area in terms of underground water level and flooding water depth. As shown below, it was found that ES can be estimated based on this underground water level, and that total existing water** can also be estimated from the underground water level and flooding water depth.

6) Evaporation from soil surface before flooding (ES)

ES can be estimated from Fig. 3 which shows ratio of ES to EP at various underground water levels for heavy clay soil. It

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* Supplementary supply, so called in the Muda area, refers to irrigation water supply after rice transplanting.

** Total existing water (TEW): a new terminology proposed by the author. TEW = (Increment of soil water caused by rising underground water level from 100 cm depth) + (depth of flooding water).
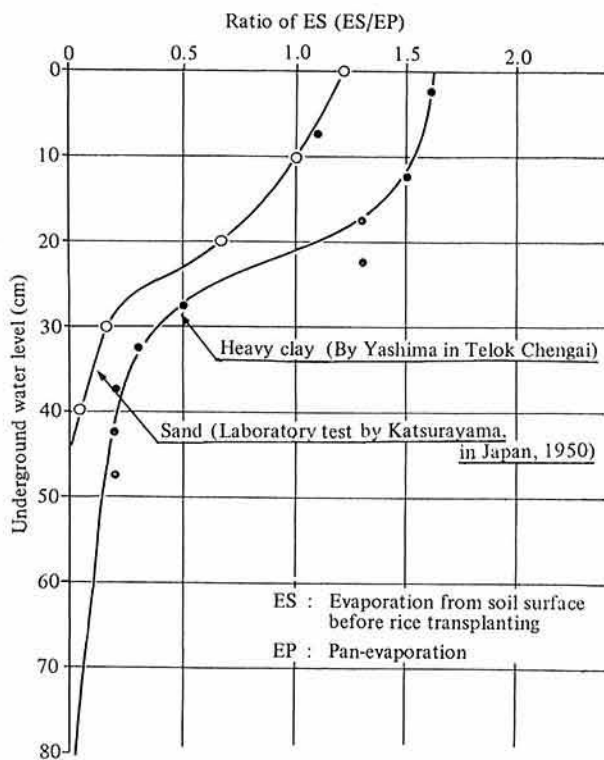
Fig. 3. Evaporation from soil surface at various
levels of underground water. (Muda,
Malaysia)

was observed in the Muda area in 1974 by
the author. The result for sandy soil in Ja-
pan[2] is also shown for comparison. When
underground water level and EP are known,
ES can be estimated from Fig. 3. In the
present study on water balance, the value of
ES in each of the 40 observation lots was
obtained first, and then its average was used
as the representative of ES for the whole
ACRBD4 irrigation block.

7) Total existing water (TEW) in field
In this paper both water requirement to
soak the soil and flooding water above the
soil surface are included into TEW. Based
on a field experiment[3] the estimated water
requirement to soak the soil was 85 mm. Fig.
4 indicates amount of TEW (in mm) at va-
rious underground water levels. The diagram
below the field surface was made by the fol-

lowing process. At first, three phases of soil
was measured at various underground water
levels down to a depth of 100 cm. The total
of the vapour phase down to the 100 cm depth
was taken as indicating water required to
soak the soil, provided that the whole vapour
phase is replaced by water after soaking the
soil, although a few percent of vapour phase
may still remain after the soaking. The
higher the underground water level, the less
is the water requirement for soaking. In-
versely speaking, the higher the underground
water level, the more water exists in the soil.
Thus, the increment of soil water caused by
rising underground water level from 100 cm
depth is taken as existing water in the soil.
The amount of existing water in the soil is
85 mm when the soil is soaked completely.
After the field surface is flooded, the amount
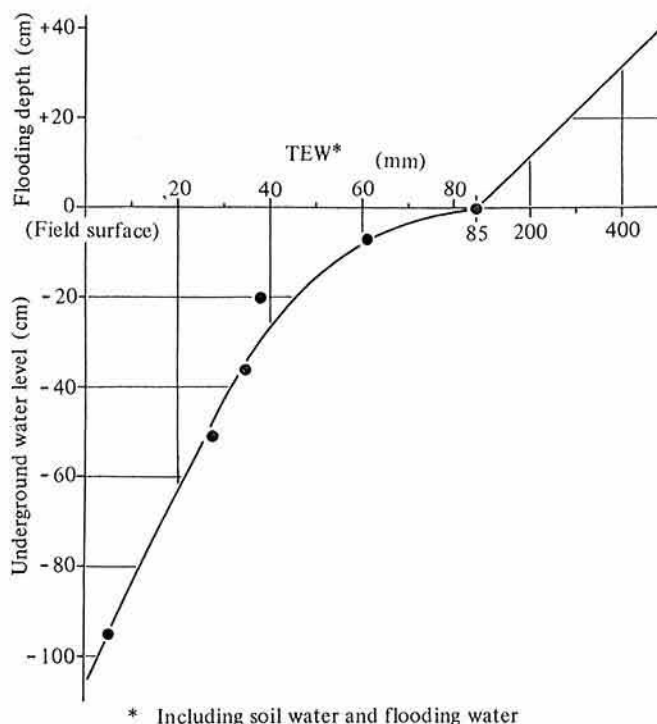of TEW becomes 85 mm plus flooding depth.

* Including soil water and flooding water

Fig. 4. Total existing water (TEW) in paddy field

Water balance

The elements mentioned above were summarized in Table 2 which shows water balance in the ACRBD4 irrigation block during the off season 1979.

The total supply for the off season was 2,092.0 mm. During the presaturation period of 61 days, the total supply was 973.8 mm of which 353.7 mm was consumed for E and ES, 208.1 mm for increased TEW and 412.0 mm for drained water or percolation. During the growing periods of rice plants of 112 days the total supply was 1,118.2 mm and the TEW decreased by 100.9 mm in the same period. The water consumption was 614.6 mm for ET and 604.5 mm for drained water. As a result, averaged daily water consumption was 10.0 mm which appears reasonable for ill-drained paddy field. It will be difficult to further reduce this consumption by the development of field infrastructure.

In comparison with the designed presatura-

tion requirement of 353 mm in the feasibility report[4], it appears that the present presaturation requirement of 973.8 mm is extremely high. Especially, the water loss is very high amounting to 765.7 mm or 79% of the total supply. On the other hand, the net presaturation requirement for only soaking and preflooding, was only 208.1 mm or 21%. Of the loss, 353.7 mm was evaporation loss. With poor infrastructure for water distribution such as plot-to-plot irrigation, more than one month time is required to irrigate the field covering a long distance of 1.5 km. Supplying water into nursery beds separately from paddy field is difficult, resulting in a prolongation of flooding period. These could be the major reasons for the high evaporation loss.

The other 412.0 mm was the loss including drained water. The intricate micro-topography mentioned before substantially obstructs water delivery in the very flat land like the Muda area. Most of the drain loss occurs when irrigation water is delivered across the

Table 1.   Evapotranspiration in paddy field

| Period | Day | Daily average (mm) | | | | E T | E | T |
		E P	E T	E	T	E P	E P	E P
5–10 April	6	7.1	7.2	6.6	0.6	1.01	0.93	0.08
11–20 April	10	5.7	6.2	4.9	1.3	1.09	0.86	0.23
21–30 April	10	5.3	5.9	4.2	1.7	1.11	0.79	0.32
1–10 May	10	6.3	7.4	4.0	3.4	1.17	0.63	0.54
11–20 May	10	5.0	6.7	3.1	3.6	1.34	0.62	0.72
21–31 May	11	4.9	6.5	1.8	4.7	1.33	0.37	0.96
1–10 June	10	4.1	6.4	1.9	4.5	1.56	0.46	1.10
11–20 June	10	4.2	6.1	1.4	4.7	1.45	0.33	1.12
21–30 June	10	4.3	5.7	1.3	4.4	1.33	0.30	1.03
1–10 July	10	4.6	4.6	0.9	3.7	1.00	0.20	0.80
11–20 July	10	4.8	6.2	1.0	5.2	1.29	0.21	1.08
21–31 July	11	3.6	3.7	0.7	3.0	1.03	0.19	0.84
1–10 August	10	4.2	4.2	1.2	3.0	1.00	0.29	0.71
Total or Average	128	622*	751*	307*	444*	1.21	0.49	0.72

Observed in ACRBD4 irrigation block, Muda, Malaysia during the 1979 off season.

  EP: Pan evaporation observed by ϕ 120 cm pan
  ET: Evapotranspiration in paddy field
  T :   Transpiration in paddy field
  E :   Evaporation (ET−T)
  * :   Total quantity in water depth

Table 2.   Water balance in the ACRBD4 irrigation block, Muda, Malaysia during
           the 1979 off season

(Unit: mm)

| Period | Supply | | | | Net consumption | | |
| | Controlled | Uncontrolled | | Total | E & T | Total existing water | Other |
		River	Rain				
Presaturation supply (61 days)							
1–10/March	164.1	1.8	0.5	166.4	44.2	65.1	57.1
11–20/March	115.5	0.3	0.0	115.8	64.6	13.3	37.9
21–31/March	197.5	3.4	17.5	218.4	75.2	44.3	98.9
1–10/April	87.5	15.2	40.0	142.7	63.2	15.2	64.3
11–20/April	120.1	1.1	23.5	144.7	54.2	47.1	43.4
21–30/April	8.3	60.5	117.0	185.8	52.3	23.1	110.4
Sub total	693.0	82.3	198.5	973.8	353.7	208.1	412.0
Supplementary supply (112 days)							
1–10/May	0.0	46.4	59.5	105.9	74.1	− 53.2	85.0
11–20/May	0.0	61.2	30.5	91.7	60.7	− 24.6	55.6
21–31/May	81.2	5.8	99.0	186.0	64.7	66.7	54.6
1–10/June	50.9	37.3	41.5	129.7	51.1	− 5.8	84.4
11–20/June	0.0	114.3	76.5	190.8	55.8	8.6	126.4
21–30/June	8.5	18.7	25.5	52.7	51.7	− 50.2	51.6
1–10/July	48.8	0.0	68.0	116.8	43.8	− 2.3	75.3
11–20/July	0.0	0.0	43.0	43.0	56.9	0.8	−14.7
21–31/July	0.0	0.0	70.5	70.5	36.7	21.7	12.1
1–10/August	0.0	0.2	71.0	71.2	50.7	− 45.8	66.3
11–20/August	0.0	14.4	45.5	59.9	68.8	− 16.8	7.9
Sub total	189.4	298.3	630.5	1118.2	614.6	−100.9	604.5
Total	882.4	380.6	829.0	2092.0	968.3	107.2	1016.5
%	42.2	18.2	39.6	100.0			
%				100.0	46.3	5.1	48.6

micro-topography. Cracks on ridges and in subsoil due to desiccation in dry season are the causes of the drain loss. Damages on ridges due to agricultural machinery which travel from field to field by crossing the ridges also reduce function of the ridges to retain water.

The on-going Muda II Project aims to intensify the canal density from the present 10 m/ha to 35 m/ha. The study on changes in water balance associated with this increase in canal density is being in progress in the pilot area of the ACRBD4 irrigation block and the result will be reported later.

Summary and conclusion

Water balance of low and flat paddy field was studied in the Muda Irrigation Project area in which plot-to-plot irrigation is practiced under low canal density of 10 m per ha.

During the off season 1979, from 1st March to 20th August, a total water supply of 2,092 mm was observed. Water consumption during presaturation period before transplanting of 61 days was extremely high amounting to 973.8 mm, of which 765.7 mm or 79% was consumed as water loss that included evaporation of 353.7 mm and drained water of 412.0 mm. During the period from transplanting to maturing of 112 days, a total of 1118.2 mm was supplied by irrigation and precipitation. Water consumption was 614.6 mm for evapo-transpiration and 604.5 mm for drained water. Consequently, the existing water was decreased by 100.9 mm. An increase in irrigation canal density will be effective to reduce presaturation requirement.

It is considered that major reason for the great loss amounting to 79% is the prolonged presaturation period due to difficulties of implementing separated irrigation between nursery beds and main fields and to intricate microtopography which obstructs water delivery. On the other hand daily water consumption of 10.0 mm during the growing period of rice plants in the present study is a reasonable value for ill-drained paddy fields.

References

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