

WATER BALANCE OF RICE ON THE GRUMUSOLS IN THE COMMAND AREA OF GIANT'S TANK

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INTRODUCTION

There have been few detailed water balance studies carried out on rice in Sri Lanka, and such studies as there are have been confined to the humic gley soils and the well and poorly drained red brown earths (Rasiah, 1980; Holmes *et al* 1980). Nevertheless knowledge of not only the evapotranspiration needs of a rice crop but also the field water requirements associated with land preparation, wetting of the soil and vertical and lateral drainage during the growth of a crop provide an overall picture of the water balance of a rice field (Bolton, 1980), in addition to essential information for a rational programme of planned water use and management of irrigation schemes.

The work of Wickham and Singh (1977), Wickham and Sen (1978) and Tomar and O'Toole (1978), demonstrates not only the regional variability in crop evapotranspiration but importance of variation in soil characteristics and cultural procedures on the value of such components as vertical and lateral drainage in the overall water balance. Their work demonstrates the need for soil and regional specific rice water balance studies.

This study was carried out on the grumusols, order Vertisols, (Moorman and Panabokke, 1961, De Alwis and Panabokke, 1972) of the Mannar District in the command area of the Giant's Tank in the north west Dry Zone of Sri Lanka. This area has a mean annual rainfall of 1112 mm per year but a bimodal rainfall pattern means that only the maha (major) cultivation season in November to January is normally assured of water supplies from rainfall and tank issues while the yala (minor) season in April to June usually suffers severe water constraint through low rainfall and low water reserves in the tank and as a result only a limited area of rice can be cultivated.

The results reported here describe not only the lysimetric studies carried out on rice grown on the grumusols but also contrast these empirical measurements with the practice of irrigation from the Giant's Tank.

MATERIALS AND METHODS

The study was carried out at Murunkan Seed Farm, Murunkan, Mannar district during the yala season of 1980 and the maha of 1981.

A set of seven tanks (Wickham and Sen, 1978) 1.22m x 1.83m and 0.76m deep were constructed from gauge 18 metal sheeting; three tanks with bottoms were used for measuring evapotranspiration losses and a fourth tank with bottom was used for open water evaporation measurements. Three tanks were without bottoms and these were used to measure evapotranspiration (ETC) and percolation (P). The seven tanks were installed randomly allocated along an axis in the centre of a paddy field, the bottomless tanks being driven into the ground and the tanks with bottoms into a previously dug pit. The soil was replaced in these latter tanks in the reverse order to which it had been dug out. In order to minimise water level fluctuations in the area surrounding the lysimeters, an earthen bund of 10.6 m x 20m was constructed to enclose them. During the maha an expanded bund of 20 x 30m was lined with polythene to a depth of 0.6 m to minimise seepage and lateral drainage. Changes in water level in the lysimeters were measured by means of a screw gauge attached to a fixed plate on the tank during yala but during the maha a hook pointing downwards was welded to each tank and a measured volume of water was added to bring the level up to the hook.

Measurements of change in depth of water in the area surrounding the lysimeters and in farmer fields were carried out using a wooden sloping gauge of 1.10 slope (Giron and Wickham, 1976; Bolton, 1980).

Rice variety Bg 34-8 (3 month variety) was grown in the yala and Bg 94-1 (3 1/2 month variety) was grown in the maha. For the yala crop, the rice seedlings were transplanted on the 16 May 1980 and for the Maha on the 28 December. All cultural practices followed the Department of Agriculture recommendations. A basal dressing of 222 kg/ha of urea, 108 kg/ha of conc. superphosphate and 60 kg/ha muriate of potash was applied. At 2 weeks after transplanting an application of 78 kg/ha of urea was given and at 5 weeks top dressing of 100 kg/ha of urea and 50 kg/ha of muriate of potash was applied.

The lysimeter tanks were treated and planted in the same way and at the same time as the surrounding paddy fields. During paddy growth, measurements of changes in the water level within the lysimeters were taken every day or once in two days, starting eight days before the seedlings were transplanted.

Rain gauges were used in both seasons and during the maha a Class A pan and an anemometer were also installed in the field. Rainfall, wet and dry bulb temperature, sunshine hours and Class A pan measurements were taken from the meteorological site at the research unit of the Government Seed Farm, Murunkan.

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RESULTS AND DISCUSSION

1. Water Losses through Evapotranspiration and Percolation

(a) *Yala season 1980*

The rates of evapotranspiration (ET_C) and percolation (P) are shown in Fig. 1. These data show that the rate of ET_C started initially at 6.1 mm/day and rose to a maximum rate of 9.8 mm/day. This is well within the range of 4–9 mm/day reported by Wickham and Sen (1978) for the rice growing areas of Asia. The average rate of ET_C was 8.5 mm/day which gave a total value for ET_C during the cropping period of 631 mm.

For the period 60–70 days after transplanting there was insufficient water in the field channels for irrigation and both the fields and tanks dried out and cracks appeared on the surface of the soil. As has been reported by Wickham (1974), puddled soils of moderate to high clay content if allowed to dry out and then rewetted, fail to re-seal initially and high percolation losses result; this was observed in the study reported here and accordingly the results for the 60–70 day period and immediately afterwards have not been incorporated and calculations for ET_C and P for this period have been extrapolated from just before the 60–70 day period and from 75 days onward.

Percolation losses, which were measured from 16 days after the soil was initially wetted, averaged 2.4 mm/day for the first ten day period and increased to 9.9 mm/day by the seventh day period. The rate of percolation for the eighth ten day period was 20.6 mm/day (see above) but this declined to 10 mm per day during the last stage. The total water loss due to percolation from the ten day period before planting to harvest was 567 mm.

(b) *Maha season 1980/81*

As with the yala experiment, water from the irrigation channel ran short although by transporting water it was possible to keep the lysimeters moist and continue measurements of ET_C . The whole period of irrigation was 25 days before transplanting and for 100 days after transplanting.

The rates of ET_C and P are shown in Fig. 2. The rates of ET_C rose from 4.1 mm/day to a maximum of 7.4 mm/day and assuming that the rate of ET_C was constant after 70 days from transplanting, the total water loss through ET_C was 612 mm over 100 days. The rates of P started at 3.8 mm/day and reached a maximum of 10 mm/day at 70 days after transplanting. Assuming that the rate of percolation was the same for 70–100 days after transplanting, the total water loss due to percolation was 935 mm over 130 days.

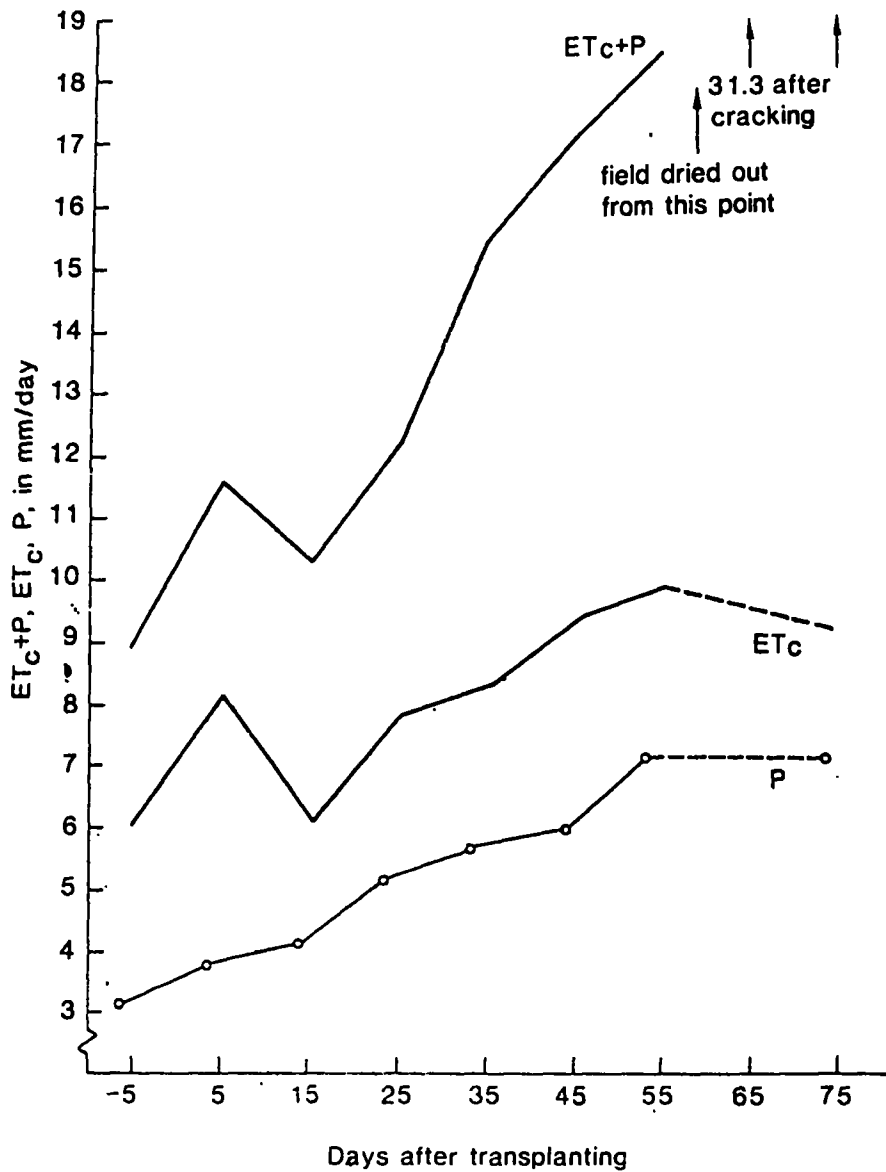


Figure 1. Rates of crop evapotranspiration (ET_c) - percolation (P) from bottomless tanks, crop evapotranspiration from tanks with bottoms, and percolation (by deduction)

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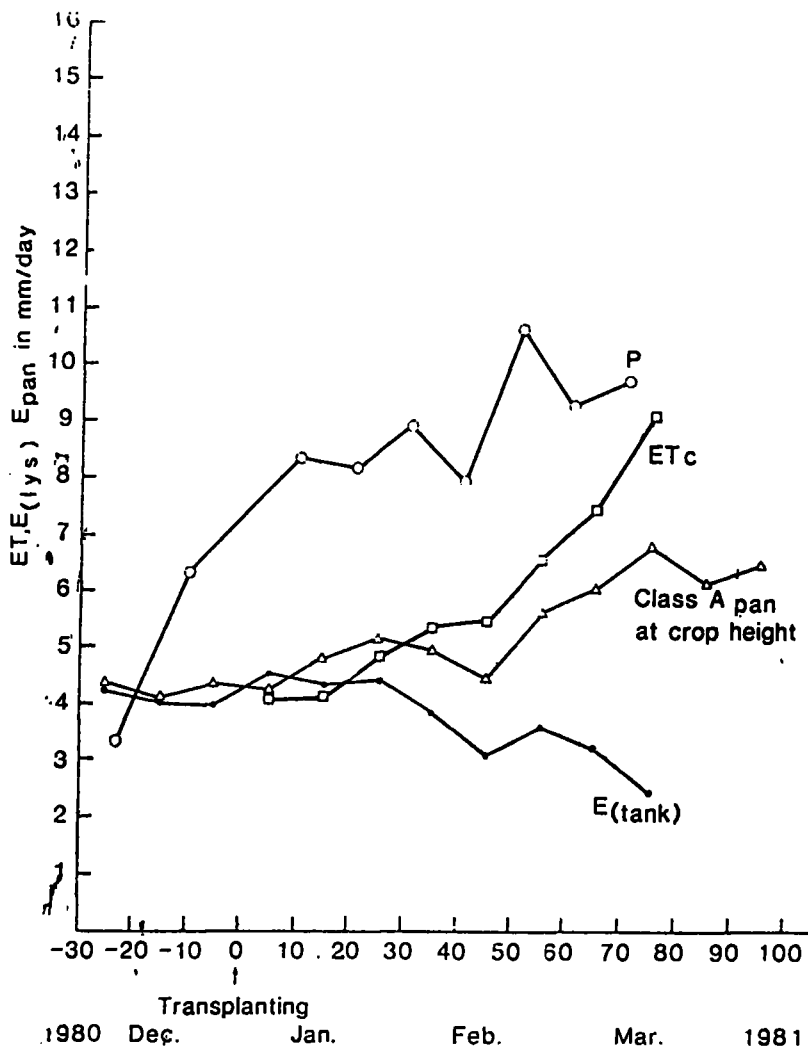


Figure 2. Rates of crop evapotranspiration (E_c), Class A Pan evaporation at crop height (E_{pan}), evaporation from an uncropped tank (E_{tank}) and percolation (P)

(2) Water Requirement for Initial Soil Wetting before Land Preparation.

An important component in the overall water balance of paddy is the determination of the amount of water required to wet the soil during land preparation. It is difficult however under field conditions to quantify the actual amount of water needed and it was decided to follow the studies of Valera and Wickham (1978) and IRRI (1976) and to utilize the derived equation for the determination of the saturation requirement. This equation is as follows:

$LS = d \times mc \times As$ where LS = amount of water to saturate the soil in mm
 d = depth of soil to be saturated
 mc = change of moisture content from dry soil to saturation on a dry basis
 As = apparent specific gravity which is numerically equal to the ratio of the soil bulk density to that of water.

Soil samples collected before any rains or irrigation was applied to the grumusols showed that to a depth of 30 cm, the grumusols dried to a soil moisture content of 12%. Saturated soil samples collected from the lysimeter site after irrigation had a soil moisture content of 46%. On the basis of an apparent soil specific gravity of 1.87, the amount of water required to saturate the soil to depth of 300 mm was determined as 190.7 mm, although this should be treated as a minimum value (IRRI, 1978).

(3) Field Water Requirements

The conveyance and seepage losses for the transport of water to the experimental site was not estimated in this study and results presented in Table 1 indicate the components of water use or loss just within the experimental site and show that the field water requirements were 1624 and 1930 mm for the yala and maha season respectively.

The results show that the average daily rate of ET_c was higher in the dry season (yala) than in the wet (maha) season (8.5 and 6.0 mm/day respectively), a difference which could be attributed to higher levels of net radiation in the yala. However, percolation in the yala was lower than in the maha (6.3 and 8.8 mm/day respectively) and a possible explanation could be the greater depth

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of irrigation water maintained during the Maha (4–5 cm) due to greater water availability. The depth of the water table at Murunkan was too great (10m) for it to have any effect on water movement.

Estimates of field water use using sloping gauges, following Giron and Wickham (1976) and IRRI (1976) sited near the lysimeters, at an additional site on the Murunkan Seed Farm and on three farmers' fields, found field water use figures ranging from 9.1 mm/day to 20 mm/day, the higher figures being found on a farmer's field which had a higher sand fraction than the other sites. These values compare with the daily field water use figures for the lysimeter study during the period of rice growth of 14.8 mm for both the yala and maha season. Using ET_C derived from the lysimeter study it is possible to calculate the variation in daily rates of percolation between the sloping gauge measurements and the lysimeter measurements on the Murunkan Farm. These figures were 4.1 mm/day for the sloping gauges compared to 6.3 mm/day and 8.8 mm/day for the yala and maha readings. It is not clear whether these differences do actually reflect site differences due to variation in soil textural composition or depth of water table, or that the enhanced values at the lysimeter site were due to a soil/tank interface effect on percolation.

(4) Estimation of Reference Crop Evapotranspiration (ET_C)

An important use of empirical data on ET_C derived from lysimeter sites is that it enables the calculation of regional crop coefficients for the various stages of crop growth, which in conjunction with ET_0 values derived from climatic data (Doorenbos and Pruitt, 1977) or pan data, can be used to derive regional figures for ET_C .

However no Penman estimates were possible for Murunkan due to incomplete climatic data. Nor was it possible to utilise data from Mannar, Maha Illuppallama or Vanathavillu (Fig. 3b) because of lack of comparability with Murunkan climatic conditions (Bandara, 1981). Therefore ET_0 was estimated on the basis of Pan data (Doorenbos and Pruitt, 1977) using a correction factor for the screen used and a pan coefficient (k_p) for the given conditions of wind, relative humidity and surrounding vegetation (Bandara, 1981). Figure 3 a & b shows the E_p and ET_0 figures derived from a class A pan at Murunkan met. station and a class A pan at crop height. Values of ET_0 from the different pans ranged from minimum of 1.9 mm/day in mid November 1980 to a maximum of 5.4 mm/day in March 1981.

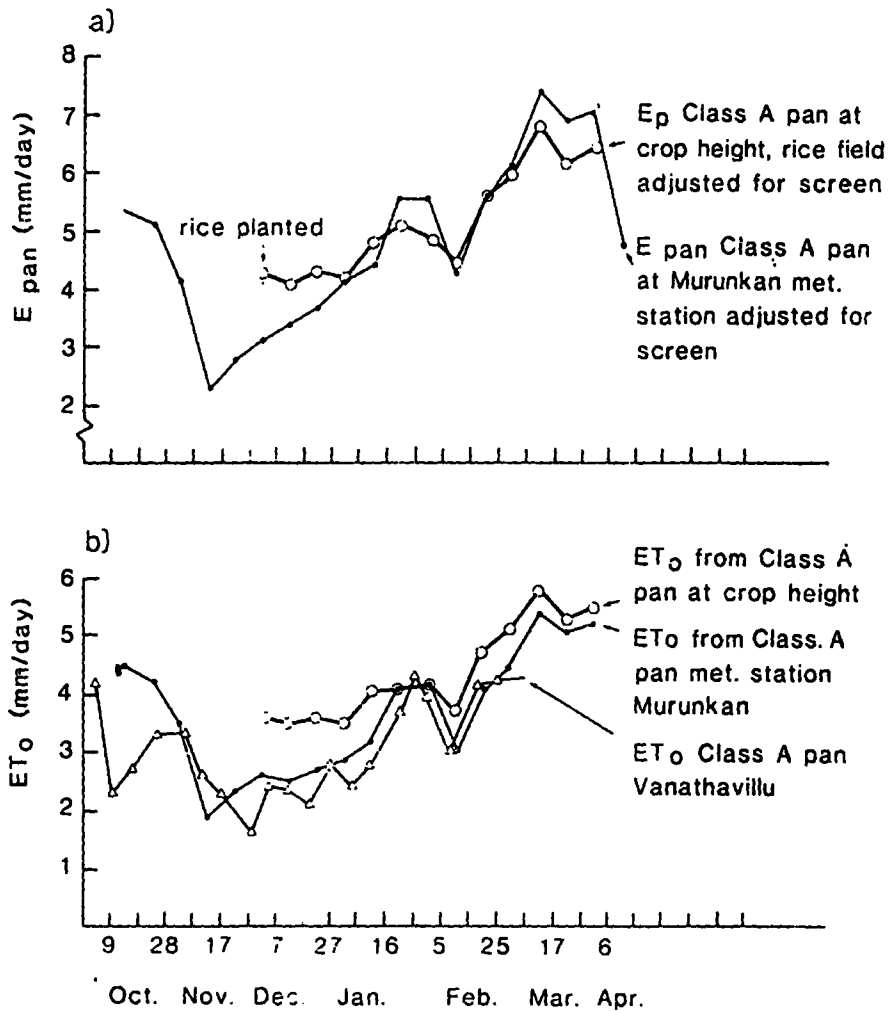


Figure 3. a) Class A pan evaporation in the rice field and in the meteorological station and
b) at crop height in the rice field contrasted with ET_0 derived from Class A pan at Murunkan met. station, and from a Class A pan at Vanathavillu

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The crop coefficient (K_c) is defined as the ratio between crop evapotranspiration (ET_c) and reference crop evapotranspiration (ET_o) under optimum growing conditions in large open fields (Doorenbos and Pruitt, 1977). It can also be calculated from the ratio ET_c/E_{pan} . For maha 1980/81 growing season K_c values for rice were calculated by dividing the lysimeter ET_c values by the following denominators:

- (a) ET_o — Class A pan, Murunkan, met. station.
- (b) ET_o — Class A pan, crop height in the rice field.
- (c) E_{pan} — Murunkan met. station.
- (d) E_{pan} — crop height in the rice field.

The calculated crop coefficients for the various stages of growth are shown in Table 2 and a comparison of these K_c factors with other crop coefficients derived for Sri Lanka and the Asian region is summarised in Fig 4 a & b to emphasise the main similarities and discrepancies in the various crop coefficients. It should be noted that the mid season values given in Tomar and O'Toole (1978) model, based on data from Malaysia, Vietnam, Phillipines, Japan and Australia, are in agreement with the Murunkan figures and Eavis (1977); however there are big differences at the 10–25 day period between the data of Tomar and O'Toole (1978) and that reported here although this could well be due to differential varietal response and recovery from the effect of transplanting.

However if ET_o derived from the pan data for Murunkan is corrected according to Doorenbos and Pruitt (1977) to take account of siting and other effects then the crop coefficient curve changes from curve A1 to curve A2 (Fig 4 a and b) and this modified curve indicated higher crop coefficient values than those ET_c/ET_o values given by Joshua (1977) and Doorenbos and Pruitt (1977). This suggests that the corrections for the pan data to convert E_{pan} into ET_o may be inappropriate for Murunkan, as was also found for Vanathavillu (Kuruppuarachchi, 1981). However proof of this would require determination of ET_o values for Murunkan.

From the results reported here, it is suggested that the coefficients ET_c/E_{pan} derived at Murunkan be used for irrigation planning rather than ET_c/ET_o . Table 3 gives the recommended crop coefficients for the various stages of rice growth derived from a smooth curve based on lysimeter and pan data from Murunkan and it is suggested that these could be used for maha rice in other areas of Sri Lanka where lysimetry data is not available.

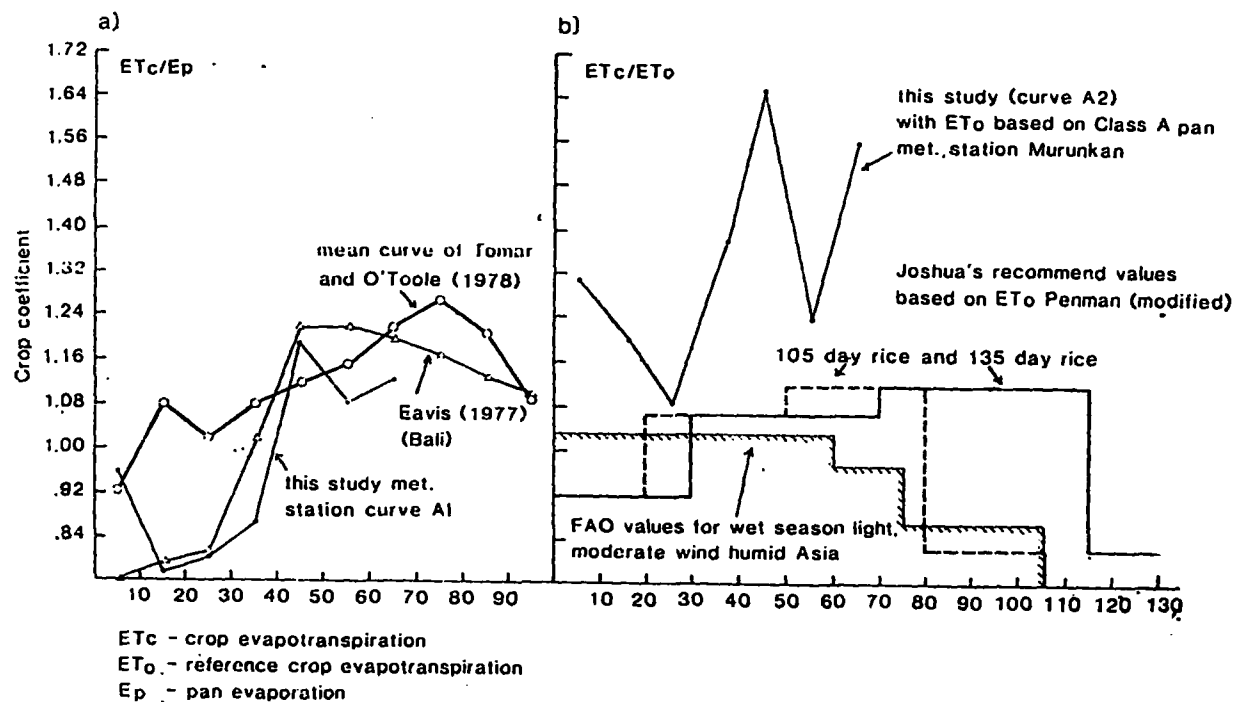


Figure 4 Comparisons between ET_c/ET_0 and ET_c/E_p and various published crop coefficients for rice.

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CONCLUSION

During the period maha 79/80 of the lysimeter studies, data were collected for the estimated issue of water from the seven sluices of the Giant's Tank and it was determined that 7037 ha m were issued during the maha 79/80 (Bandara, 1981). The rainfall for this period was 903 mm and using the lysimeter estimation of total field water requirement for this period of 1930 mm, it was calculated that the balance required from the tank was 1,027 m/ha. On this basis the theoretical area which could be irrigated from the Giant's Tank was $7037/1.027$ or 6852 ha. However the reported area of cultivation under these sluices for the season was 11,000 ha which implied that the volume of water estimated to be available from the Giant's Tank was only 60% of the calculated need. It should be noted that lack of irrigation water is a major complaint of many cultivators. There are several possible reasons for this discrepancy; firstly actual issues from the sluices could have been underestimated, secondly the area under cultivation could have been overestimated; thirdly possible contributions from the minor tanks towards meeting irrigation requirements were not taken into account; fourthly overestimation in the lysimeter studies of actual percolation losses, and fifthly possible contribution of water from the water table in parts of the command area. It is difficult however to attribute any relative importance to any of the above factors.

Clarification of the first three factors would require detailed survey of cultivated land and detailed measurement of both upstream and downstream height of outflow from the sluices along the inlet channel and studies on the water balance of the minor tanks. The influence of percolation on ground water and the possible re-use of such water further downstream would also require further investigation to satisfy the final point.

Comparison of the percolation figures found in these studies with those reported by Rasiah (1981) for other dry zone soils suggests that the figures are comparable. Under paddy, well drained red brown earths have higher percolation losses than those found for the grumusols and those on the poorly drained red brown earths and the low humic gleys have lower values; direct comparisons though should be treated with caution, not least because of the importance of groundwater contribution to the overall water balance when the rice soils are in catenary sequence on slopes as the well drained, poorly drained red brown earths and the low humic gleys often are.

The evidence presented however suggests on the basis of the data collected that water use efficiencies in the Giant's Tank command area are high. Any potential for improvement would depend on clarification of the reliability particularly of water issue figures and the extent or area under cultivation.

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Table 1 Seasonal water use of rice (lysimeter study) Murunkan, 1980/81

Function	Duration (DAT)	Yala			Soil saturation	Maha			Soil saturation
		E	ET _c	P		E	ET _c	P	
		in mm				in mm			
Soil saturation	—	—	—	—	(191)	—	—	—	(191)
Land preparation	-21-10 -9-1	60.5 60.5	—	23.8 23.8	—	40 39.7	—	63.5 64.3	—
Plant growth	1-10 11-20 21-30 31-40 41-50 51-60 61-70 71-80 81-90 91-100	— — — — — — — — — —	80.7 60.8 77.6 82.4 93.7 98.5 95.3* 92.0	35.2 41.3 61.2 70.7 75.8 99.7 99.8* 99.9	— — — — — — — — — —	— — — — — — — — — —	40.5 41.5 47.8 52.8 54.2 64.9 73.8 73.8** 73.8** 73.8**	84.4 82.4 89.5 81.1 107.3 94.3 98.9 98.9** 99.9** 98.9**	— — — — — — — — — —
Total		121	681	631	191	79.7	59.7	1062.4	191
Average, day		6.05	8.5	6.3	—	4.0	6.0	8.8	—
Overall demand			16.24mm				1930.1 mm		
Rainfall			80.5 mm				70 mm		
Irrigation requirement			1543 mm				1853.1 mm		

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* Assuming the mean of previous and subsequent values

** Assuming the same rates of previous value.

DAT —days after transplanting

E —evaporation

ET_c—Crop evapotranspiration

P—percolation

Table 2 Crop coefficient estimates by this study

Location and variety	Basis for (ET_c/ET_0) or coefficient (ET_c/ET_{pan})	Stages of growth (days after transplanting)							
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80 80-90 90-100
			1st month			2nd month		Mid season	
Murunkan 105 day variety	1. ET_c/ET_0 'A' pan met station	1.39	1.29	1.17	1.40	1.74	1.32	1.64	not available
	2. ET_c/ET_0 'A' pan crop height	1.15	1.01	1.17	1.28	1.46	1.37	1.45	not available
	3. ET_c/E_p 'A' pan met station	1.04	0.86	0.89	0.95	1.23	1.17	1.21	not available
	4. ET_c/E_p 'A' pan crop height	0.98	0.86	0.95	1.08	1.23	1.17	1.23	not available

ET_c —crop evapotranspiration

ET_0 —reference crop evapotranspiration

E_p —pan evaporation

Table 3 Recommended crop coefficients for maha, Sri Lanka, wet land rice 105 days varieties for the first 70 days

Period	ET_c/E_{pan}^*
0-10	0.86
10-20	0.86
20-30	0.88
30-40	0.95
40-50	1.24
50-60	1.22
60-70	1.20

* E_{pan} is based on a Class A pan in met station in an area of short grass which was not irrigated.