Measurement of deep percolation losses under flooded rice system in Cununurra clay soil

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Key messages

Excess groundwater recharge rates under irrigated agriculture may lead to problems such as rising watertable, waterlogging and salinity. In recently developed areas, industry may be required to manage this water and hence, understanding what leakage is attributed to what crops will become more important.

We estimated evaporation, transpiration and deep percolation losses for a flooded rice crop in Cununurra clay soil using a range of measurement systems.

The results show that deep percolation losses were less than 1 mm/day. Total crop leakage from flooded rice fields was approximately 88 mm for the 90 day production period cycle.

Aims

Areas of irrigated agriculture are prone to rising groundwater, waterlogging and salinity under poor irrigation practices. In extreme cases, these negative effects may lead to loss of cropping land or create costs of management which may need to be borne by industry. Previous flooded rice systems in Kununurra are attributed to have contributed to excess groundwater recharge rates. We took a water balance approach to determine the evaporation, transpiration and deep percolation losses from flooded rice bays on Cununurra clay soil during the dry season of 2013.

Method

The study was conducted on Cununurra clay soil (Self-mulching Vertosol) at Frank Wise Institute of Tropical Agriculture in Kununurra under ponded rice culture (flooded system) during the period from 10 June 2013 to 2 October 2013 (90 days). We used 'lockup bay tests' as proposed by Humphreys (1992) together with a modified lysimeter experiment (Bethune *et al.* 2001). Three lysimeters (two with open-end and one with closed-end) were used. Each lysimeter was 50 cm across and 70 cm high and driven 35 cm into the ground and sealed. One lysimeter (open-end) was installed in the cropped area with other two in adjacent bare land. By comparing losses from each lysimeter, it was possible to measure the evaporation, transpiration and deep percolation components (Figure 1). The side valve on each lysimeter was opened during each irrigation event (i.e. topping up the bay) to allow water inside.

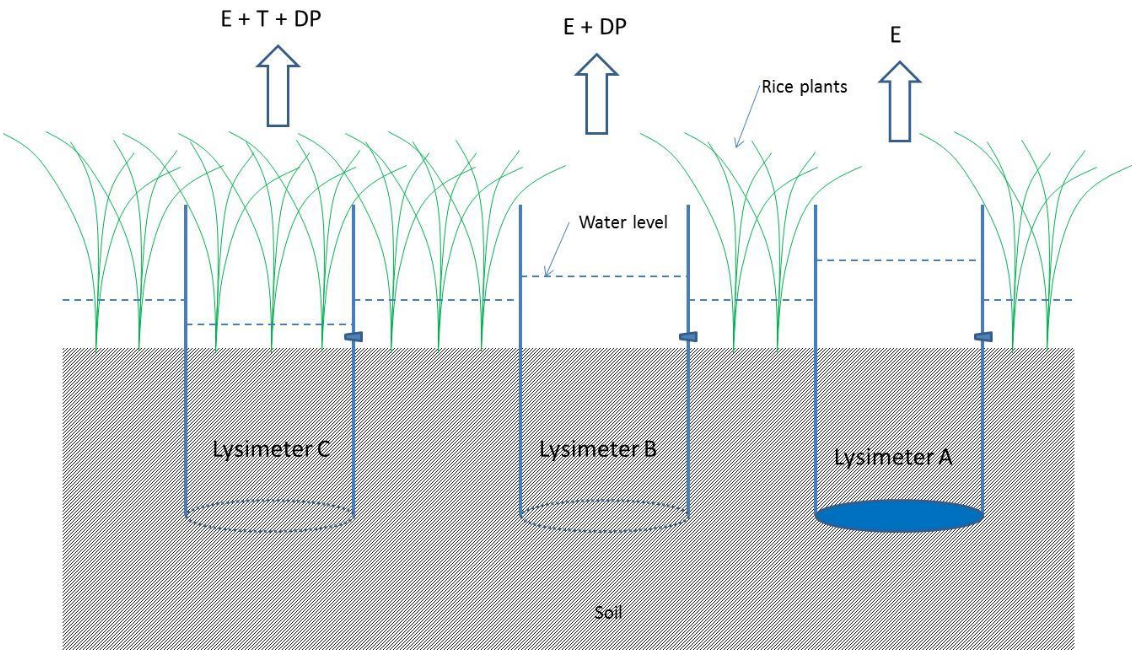

Figure 1 Diagram of lysimeters to measure evaporation (E), transpiration (T) and deep percolation (DP) losses in a paddy field, where the arrows indicate combined water losses

US Class A Pan evaporimeter was also installed at experimental site to measure actual evaporation losses in paddy field situation under FAO recommended standard conditions. Automatic water level recorders were used to monitor changes in water level within lysimeters, evaporation pan and outside surrounding field. Lateral seepage from the test bay was prevented by undertaking ponded rice culture in adjacent bays in both sides. The tail-end bank was sealed using a plastic barrier just before commencing the experiment. Lockup bay tests were conducted once the permanent water had been applied to the rice crop (10 June 2013) and continued until the bay was drained to prepare for harvest (2 October 2013). A lockup bay test involves preventing water flow between the bays (i.e. no inflow or outflow within the bay in this situation) and recording the change in water depth each day over a period of several days.

The data for water height from each logger showed variations within a 24 hour period. Therefore an average height was calculated for the 24 hour period. The average height after an irrigation event was considered as the initial height of water column. Similarly the average height before the next irrigation event was considered as the final height of water column. The difference in height between these two readings was the total amount of water loss during that time period. Water losses are expressed as loss per day (mm/day) or total loss (mm) over the period of measurement (days). For the evaporation pan, these measurements correspond to water level after and before filling the pan with water.

Results

Results for evaporation, transpiration and deep percolation calculated from the lysimeter data are shown in Figure 2. Evaporation is the water loss measured in Lysimeter A. Deep percolation is the water loss measured in Lysimeter B minus water loss measured in Lysimeter A. Transpiration is the water loss measured in Lysimeter C minus water loss measured in Lysimeter B. Data points in Figure 2 are the average water losses within an irrigation cycle.

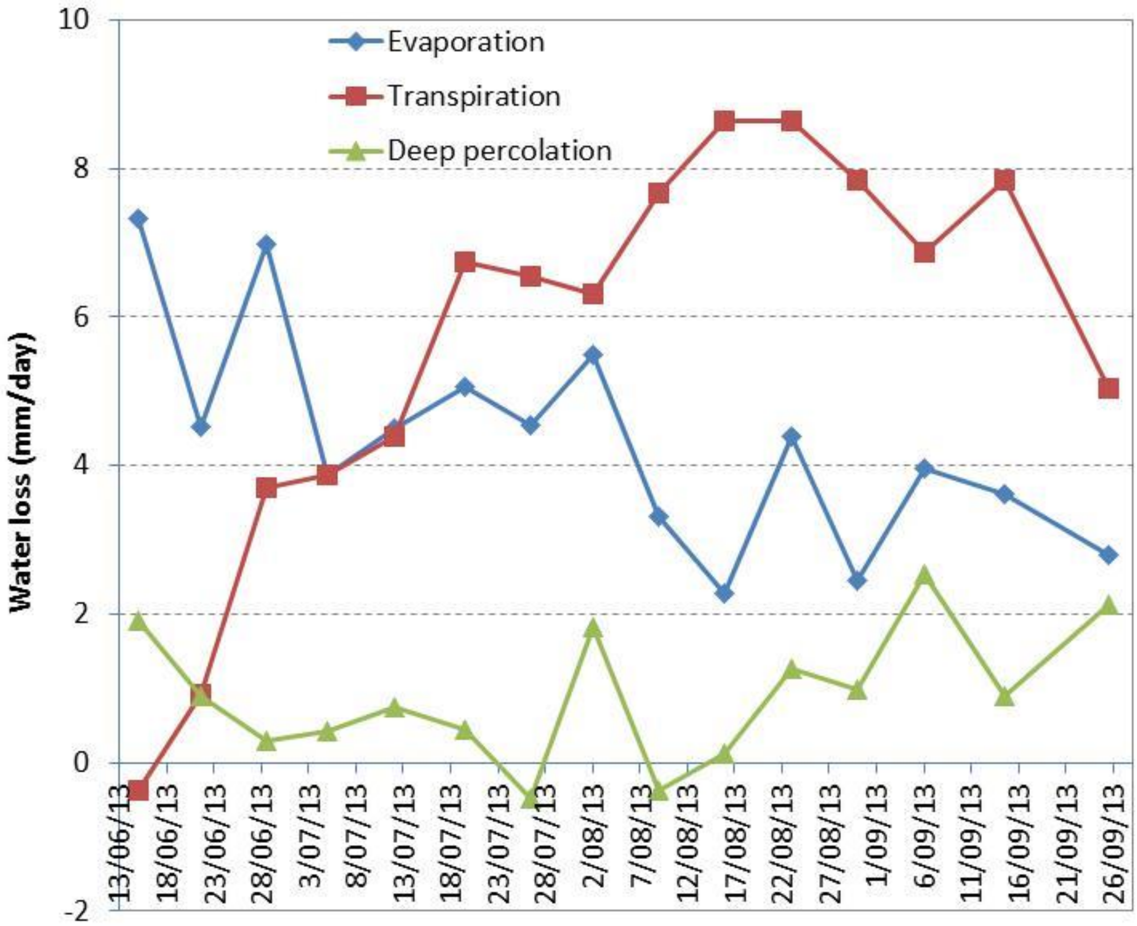

Figure 2 Evaporation, transpiration and deep percolation losses as measured by the lysimeters

There was general agreement for evaporation losses between that measured by the lysimeter A and Class A Pan. Total evaporation losses from Lysimeter A over a period of 90.5 days were 375.7 mm and from Class A Pan over a period of 91.2 days were 377.9 mm. Therefore, for the purpose of reporting evaporation losses from a flooded rice bay, data from Lysimeter A could be used. The data shows that evaporation losses were high at the beginning when the rice plants were small. But it decreased as the crop developed to full canopy which provided a shading effect to reduce the evaporation losses. When the air temperature increased in August and September, the evaporation was not affected. It appears that the shading effect was much greater than the air temperature effect on evaporation.

As expected, transpiration losses were much lower when the rice plants were small. The crop was planted on 8 May 2013 and it was 35 days old when the experiments started on 12 June 2013 with the application of permanent water. Transpiration losses increased rapidly as the plants reached full canopy and then started to decline when the plants approached full maturity. At full canopy, transpiration losses were almost double of evaporation losses. Over the period of 90.5 days, the total transpiration losses were 523 mm. The transpiration losses reported here is applicable to variety IR 72 at a population density of 200-300 plants/m^2 as maintained within Lysimeter C. It might be different for another variety and for different plant population.

The amount of deep percolation losses fluctuated approximately between 0 and 2 mm/day over the period and this may be due to the nature of measurements performed in Lysimeters A and B. The total deep percolation losses over a period of 90.5 days were 87.9 mm. Hence the average deep percolation loss over the period was 0.97 mm/day. This was less than previously reported in Kununurra, reflecting the improved crop and water management used on modern rice varieties. It also suggests that if this rate can be scaled up to a paddock and farm area, it is predicted that recharge of groundwater under extensive rice cultivation

using the traditional flooded system in Cununurra clay soils should be within manageable given existing infrastructure.

The total water losses (i.e. the sum of evaporation, transpiration and deep percolation losses) as measured by the lysimeters were compared with the total field losses as measured outside the lysimeters (i.e. field water level) in Figure 3. The lysimeter measurements indicated that the total water loss can reach a value of 14 mm/day whereas the field losses reached a maximum of 10 mm/day. This is mainly because the lysimeter had 100% cropped area while the field had only 33.1% cropped area. This difference in cropped area had direct effect on the amount of transpiration losses only. In other words, the total transpiration losses from the field were only a third of that measured in the lysimeters. Another effect will be the difference in water level within lysimeters (open-end type only) and outside, thus creating a hydraulic difference. The implication of this effect is over estimation of deep percolation losses and under estimation of transpiration losses in these experiments.

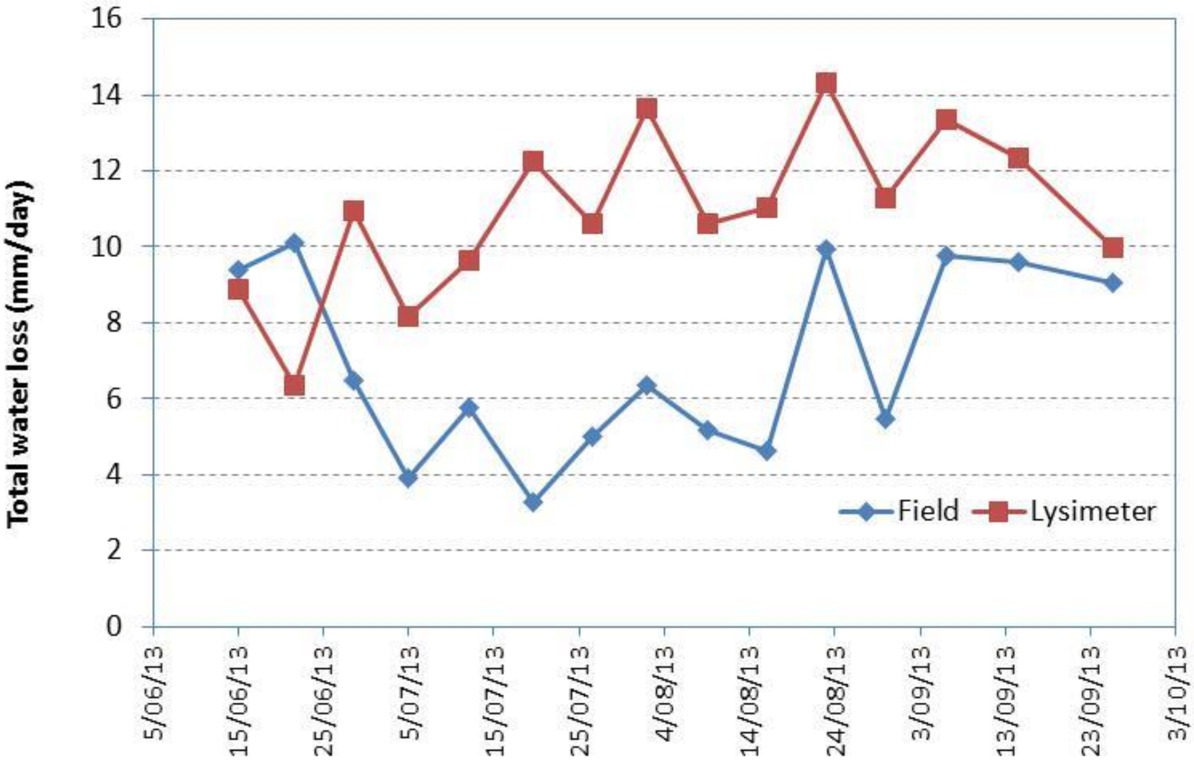

Figure 3 Total water losses from flooded rice system within lysimeters and outside in the field

The total water losses as measured by the lysimeters over the period of 90.5 days were 986.6 mm. The rice crop had ponded water for 110 days. Therefore the above measurements were extrapolated to cover the entire duration of ponding and the result is 1198.7 mm. Using a conversion of 100 mm of water depth equals to 1 ML/ha, the total water loss would be approximately 12 ML/ha. Assuming a further 1 ML/ha is used for two flushings carried out before the permanent water, the total water usage amounts to 13 ML/ha for the 2013 rice crop. This is only applicable for 110 days of ponding, for variety IR 72 and for 100% cropped area at 200-300 plants/m^2. As mentioned before, the crop water usage might be different for a different variety and for different climatic conditions where ponding duration is dependent on growth duration. Therefore it is advisable to repeat this experiment in 2014 for a different variety such as NTR 587 with 100% cropped area within lysimeters and outside field. This is necessary to conform that the deep percolation losses are in fact less than 1 mm/day and to determine the rice crop water requirement for a different variety in another season.

Conclusion

Using a set of three lysimeters and lockup bay tests, we were able to estimate the evaporation, transpiration, and deep percolation losses for ponded rice culture. The results are applicable for variety IR 72 and the growing conditions experienced in 2013. It was estimated that the total water usage might reach 13 ML/ha mark for rice depending on weather conditions. The average deep percolation losses were estimated to be less than 0.97 mm/day or approximately 1 ML/ha for the crop cycle. At this rate, deep percolation under ponded rice culture in Cununurra clay soils is within accepted leakage rates and given the experimental results are able to be scaled to bay and farm scales, the rates should not unduly affect growers or environmental managers in terms of rising groundwater levels, waterlogging and salinity, however continued experimentation is required to confirm this conclusion.

Key words

Cununurra clay soil, flooded rice system, lysimeter, deep percolation losses.

Acknowledgments

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References

Bethune M, Austin N and Maher S (2001) Quantifying the water budget of irrigated rice in the Shepparton Irrigation Region, Australia, Irrigation Science, 20: 99-105.

Humphreys E (1992) Lockup bay test guidelines, Farmers' Newsletter Large Area, 140: 45-46.

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