Irrigation scheduling for water and salinity management in the Ord Irrigation Area

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Introduction

The Ord River Irrigation Area (ORIA) is located at Kununurra in the East Kimberley region of Western Australia near the Northern Territory border. The climate is semi-arid with summer monsoonal rains, mainly between December and March; rainfall is minimal during rest of the year. The mean minimum and maximum temperatures are around 14 and 30° C in July and 25 and 39°C in November. Pan evaporation is around 3000 mm/year for the Kununurra area (Ruprecht and Rodgers, 1999).

The dominant soil types in the ORIA include cracking clays from the Cununurra and Aquitaine families (Schoknecht and Grose, 1996). Levee type soil and sands also exist. The Hydrogeology of the ORIA consists of superficial sediment overlying a palaeo-topographic surface of basalt, sandstone and limestone. Irrigation commenced during late sixties in the Ivanhoe and Packsaddle plains of the ORIA.

Prior to irrigated agriculture, the depth to shallow groundwater was relatively deep in the ORIA. With the commencement of irrigated agriculture, the groundwater levels started rising due to vegetation clearing, increased deep drainage below irrigated fields, and leakage from unlined supply channels and drains servicing the area. Since 1965, the water table has risen substantially and is now relatively close to the soil surface in some parts of the Ivanhoe Plain and Packsaddle Plains. Due to the changed hydrological conditions, the chemistry of groundwater probably changed over time (Salama *et al.*, 2002). The shallow groundwater varies throughout most of the ORIA with Electrical Conductivity (EC) levels ranging from 50 to 2160 mS/m (Ali *et al.*, 2002). In some parts of the Ivanhoe and Packsaddle plains, the shallow groundwater salinity (EC) is at extreme levels. Because the groundwater is shallow and saline in the ORIA, the risk of developing the soil root zone salinity is high. This research evaluated water and salinity management strategies for the maize and sugarcane crops grown on Cununurra clay in the ORIA. The impacts of both fresh and saline shallow water ,tables on the water demands and soil root zone salinity were evaluated through modelling. The objectives were to:

1. evaluate the existing irrigation practices for maize and sugarcane crops and quantify water losses in the form of deep drainage and runoff;
2. devise optimum irrigation strategies that will help improve water use efficiency, reduce deep drainage and runoff, and minimise salinity risks; and
3. assess the impacts of fresh and saline shallow water tables on crop water requirements and soil root zone salinity.

Material and methods

The LEACHC version of LEACHM (Hutson and Wagnet, 1992) was selected for irrigation scheduling and assessing the impacts of various fresh and saline shallow water tables on soil salinity built up when the Maize and Sugarcane crops are grown on the Cununurra Clay. Before its use this model was calibrated by collecting the field data about soil physical properties; irrigation frequency and application amounts; and soil moisture, water table depth, and soil and water chemistry from two experimental sites, Kimberly Research Station site (KRS-7A) and Cummings Farm Site (CUM55). The data were collected from two locations at each site and processed to use as input in the model for its calibration. The experimental crop at KRS site was Maize grown during 2004. In total 10 irrigation applications were applied throughout the growing period and during each watering, 9.5 ML was applied in 12 hours to irrigate 6.6 ha of the Maize crop. At Cummings farm site (CUM 55) the experimental crop was sugarcane. About 1900 mm (946 ML) depth water was applied through 14 irrigations and around 700 mm was received from rainfall during the growing season (May, 2004 to June, 2005). The irrigation application amounts varied between 106 and 168 mm (53 - 84 ML applied as one irrigation to the 50 ha crop).

The collected field data were used to calibrate LEACHE for experimental crops at both sites. The model predictions were compared with the observed data for the soil moisture and soil salinity profiles. The agreement between observed and predicted soil moisture was reasonable except in the top layers of the soil profile. The Willmott's d-index (Willmott, 1981), a measure of the degree of agreement between the observed and predicted values, was above 0.5. The agreement between the observed and predicted EC was good. The calibrated model then was used for irrigation scheduling of the Maize and sugarcane crops to ensure the maximum irrigation water use efficiency and minimal runoff and drainage losses and risk of soil salinity.

Results and discussion

Irrigation Scheduling of Maize Crop – Deep Water Table

Irrigation application amounts equal to 100% of total bi-weekly pan evaporation and applied at 14 day intervals were found to be the best irrigation strategy for the maize crop grown over a deep water table. This strategy would require around 11 ML/ha of irrigation water during one growing season, which is about 23% less than the exiting practice. Irrigation application amounts equal to 75% of total bi-weekly pan evaporation, applied every fortnight during first half of the growing season, and 75% of total weekly pan evaporation, applied on a weekly basis during the second half of the growing season, would be a better irrigation strategy if it is feasible to change the irrigation interval from 14 to 7 days. This irrigation management practice would require around 8.4 ML/ha and the predicted irrigation water use was around 40% less than the existing irrigation practice. Most of the water savings would result from reductions in surface runoff and deep drainage. The predicted salinity risks from this irrigation strategy were minimal.

Irrigation Scheduling of Sugarcane Crop – Deep Water Table

The study found that the best irrigation strategy for a sugarcane crop grown on Cununurra clay would be irrigation application amounts equal to 50% of the total bi-weekly pan evaporation, applied every fortnight during first quarter of the growing season, and irrigation application amounts equal to 100% of total weekly pan evaporation, applied every week during rest of the season (Table 1). A total of about 2200 mm of water would be required for irrigation if the crop was irrigated when half the total available water content was depleted. This amount equates to 22 ML/ha. Around 78% of this water was predicted to be used as ET and the rest was predicted to be lost as surface runoff and deep drainage. There would not be any soil salinity risks from this irrigation strategy.

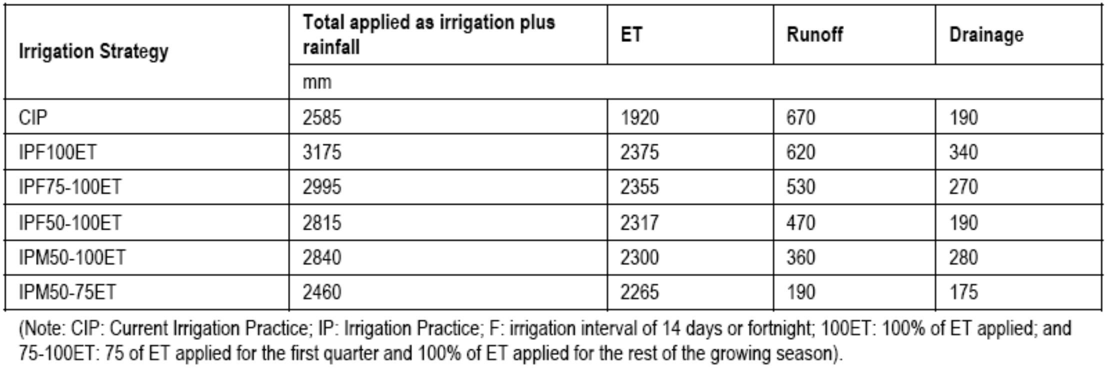
Irrigation Scheduling of Sugarcane Crop – Non-saline Shallow Water Tables

The best irrigation strategy for a sugarcane crop grown on Cununurra clay over a non-saline, shallow water table of 1 to 2 m depth would be irrigation application amounts equal to 50% of total bi-weekly pan evaporation applied every fortnight. The model predicted that this irrigation strategy would result in the best water use efficiency because it will use the maximum amount of groundwater from the shallow water table to meet the crop ET requirements. This also would help manage the water table at deeper depths. The model also predicted that this irrigation strategy would not cause excessive salt accumulation in the soil profile over time.

Irrigation Scheduling of Sugarcane Crop – Saline Shallow Water Tables

The best irrigation strategy with respect to water use efficiency will be irrigation application amounts equal to 50% of the total bi-weekly pan evaporation applied every fortnight. However, all of the simulated irrigation strategies resulted in high salinity risks. Among those evaluated the lowest salt accumulation resulted from the above irrigation strategy but it was well above the levels that can be tolerated by the sugarcane crop. Therefore, the soil salinity risks will be high if a sugarcane crop is grown for long periods over a saline shallow water table of less than 2 m depth. The best management strategy would be to first lower the water table below 2 m by artificial drainage and then to adopt the above irrigation strategy with regular leaching applications (every three months) to flush the excess salts from the soil into the drainage system.

Table 1 Total irrigation amounts, ET, runoff and drainage for various irrigation strategies for the sugarcane crop at CUM 55



Irrigation Strategy	Total applied as irrigation plus rainfall	ET	Runoff	Drainage
	mm			
CIP	2585	1920	670	190
IPF100ET	3175	2375	620	340
IPF75-100ET	2995	2355	530	270
IPF50-100ET	2815	2317	470	190
IPM50-100ET	2840	2300	360	280
IPM50-75ET	2460	2265	190	175

(Note: CIP: Current Irrigation Practice; IP: Irrigation Practice; F: irrigation interval of 14 days or fortnight; 100ET: 100% of ET applied; and 75-100ET: 75 of ET applied for the first quarter and 100% of ET applied for the rest of the growing season).

Conclusions

This study found that irrigation application amounts equal to 100% of the total bi-weekly pan evaporation, applied at 14 days interval, would be the best irrigation strategy for maize crop grown over a deep water table. The predicted irrigation water use would be around 23% less than the exiting practice. Irrigation application amounts equal to 75% of the total bi-weekly pan evaporation, applied every fortnight during first half of the growing season, and 75% of the total weekly pan evaporation, applied every week during the second half of the growing season, would be a better irrigation strategy if it is feasible to change the irrigation interval from 14 days to 7 days. The irrigation water use for this irrigation strategy was predicted to be around 40% less than the existing irrigation practice.

The best irrigation strategy for the sugarcane crop grown over a deep water table would be irrigation application amounts equal to 50% of the total bi-weekly pan evaporation, applied every fortnight during first quarter of the growing season, and irrigation application amounts equal to 100% of total weekly pan evaporation, applied every week during rest of the growing season. This irrigation strategy would require around 22 ML/ha of irrigation water for a single sugarcane crop.

The best irrigation strategy for the sugarcane crop grown over a non-saline shallow water table of ≤ 2 m depth would be irrigation application amounts equal to 50% of the total bi-weekly pan evaporation, applied every 14 days. The model predicted that this irrigation strategy would result in the best water use efficiency by encouraging plants to use groundwater to meet the crop ET requirements. The modelling results indicated that the soil salinity risks would be high if the sugarcane crop was grown for long periods over a saline shallow water table (≤ 2 m). The best management strategy would be to lower the water table below 2 m depth by artificial drainage and apply regular leaching applications to flush excessive salts into the drainage system.

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References

Ali, R., Salama, R, Pollock, D. and Bates, L., (2002). Geochemical interactions between groundwater and soil, groundwater recycling and evaporation in the ORIA. CSIRO Land and Water Technical Report 21/02.

Hutson, J.L. and Wagenet R.J., (1992). LEACHM Leaching Estimation - A Chemistry Model (A process-based model of water and solute movement, transformations, plant uptake, and chemical reactions in the unsaturated zone), version 3, Cornell University, Ithaca, New York.

Ruprecht, J.K. and Rodgers, S.J., (1999). Hydrology of the Ord river. Water and Rivers Commission: Water Resources Technical Series No. WRT 24.

Salama, R., Bekele, E., Bates, Lorraine, B., Pollock, D. and Gailitis, Vit., (2002). Hydrochemical and isotopic characteristics of the surface and groundwater of the hydrological zones of the Ord stage I irrigation area. CSIRO Land and Water Technical Report 8/02.

Schoknecht, N., and Grose, C., (1996). Soils of the Ivanhoe west bank East Kimberley Western Australia. Department of Agriculture, Western Australia, Resource Management Technical Report 155.

Willmott, C.J., (1981). On the validation of models. Physical Geography, 2(2): 184-194.