SHORT COMMUNICATION

STRATEGIC IRRIGATION DESIGN AND WATER MANAGEMENT DECISIONS: A CASE STUDY ON CENTRE PIVOTS

LECLER N L[1], ZARTMANN M[2] and SCHULZE R E[3]

[1]*South African Sugarcane Research Institute, P/Bag X02, Mount Edgecombe, 4300, South Africa.* Neil.Lecler@sugar.org.za
[2]*MBB Consulting Engineers Inc, PO Box 2821, Pietermaritzburg, 3200, South Africa.* mzartmann@mbb.co.za
[3]*School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3209, South Africa.* schulzeR@ukzn.ac.za

Abstract

A methodology whereby the *ZIMsched* 2.0 irrigation systems simulation model is used to facilitate the selection of optimal peak irrigation system design capacities and associated operating strategies is described in this short communication. In a case study simulation, the irrigation system with the highest system capacity gave the best yields of sucrose, however, from an economic perspective this was not the best system. Deficit irrigation with systems having lower peak capacities which resulted in some crop stress gave the best overall returns. Whether it was the availability of land relative to available water that limited production or *vice-versa* was a major factor in the selection of an optimal system.

Keywords: irrigation system capacity, models, economics, deficit irrigation, centre pivots, sugarcane

Introduction

The maximum water delivery capacity of an irrigation system depends on limitations of hardware which can have considerable cost, flexibility and efficiency implications. In order to provide a high water delivery capacity, larger pumps, motors, pump-houses, mainlines, sub-mains, laterals and/or canals are required. Therefore, designing or specifying irrigation systems with excess capacity can result in substantial cost implications. On the other hand, if the peak irrigation system capacity is too small, excessive crop yield losses may occur. Therefore, the development of a methodology to enable the selection of an optimal peak irrigation system capacity and associated operating strategy, for example, an appropriate deficit irrigation strategy, would be of great value. The use of the *ZIMsched 2.0* irrigation systems simulation model (Lecler, 2003) for such an application is described in this short communication.

Methodology

Crop yields and associated seasonal irrigation water applications associated with different peak irrigation system capacities were simulated using daily climate data recorded at the Zimbabwe Sugar Association Experiment Station (ZSAES) during the period 1975 to 1992. The simulations were based on the following assumptions:

- irrigation system capacity limitations equivalent to 4.3 mm/d, 5 mm/d, 6 mm/d, 7.5 mm/d, and 10 mm/d
- Total Available Moisture (TAM) equivalent to 95 mm
- gross irrigation water applications of 30 mm were scheduled to be applied once 38 mm of soil water had been depleted provided system capacity constraints were not exceeded
- a coefficient of uniformity, CU, of 90
- spray evaporation and wind-drift losses of 10%.

The economic implications of the different irrigation strategies were estimated by calculating a net return per hectare (NRH) and relative net return (RNR) using the simulated crop yield and water use information together with reasonable production cost and revenue assumptions. Equation 1 and Equation 2 respectively were used to calculate the NRH and the RNR. The RNR reflects the opportunity cost of water by multiplying the NRH by a relative production area which could be achieved using a certain fixed volume of water.

NRH = (ERC yield x ERC price) – (base production costs) – (irrigation water applied x water cost) – (irrigation water applied x electricity cost) – (ERC yield x 100/12 x harvesting and haulage cost) – (fixed irrigation interest charges) – (fixed irrigation depreciation charges) Eq. 1

RNR = NRH x (maximum water used considering all systems and seasons)/(water used for the given system and season) Eq. 2

The estimated interest and depreciation charges for centre pivot irrigation systems with different peak capacity limitations included variations due to mainline pipe sizes, pump houses and pumps but assumed in-field costs of the centre pivot infrastructure were the same. These costs ranged from R2234/ha/a for a system with a 10 mm/d system capacity to R1715/ha/a for a system with a peak capacity of 4.3 mm/d. Other cost and revenue information which was assumed to be consistent for all systems was as follows: R0.12/m^3 for water, R1.15/mm.ha for electricity, R45/t for harvesting and haulage, R4000/ha base production costs and R1250/t for the price of estimated recoverable crystal (ERC).

Results

Simulated yields of estimated recoverable crystal (ERC) and seasonal irrigation water applications are shown as cumulative frequency distributions (McPherson, 1990) in Figures 1 and 2. Cumulative frequency distributions of the NRH and RNR for the various irrigation system capacities are shown in Figures 3 and 4.

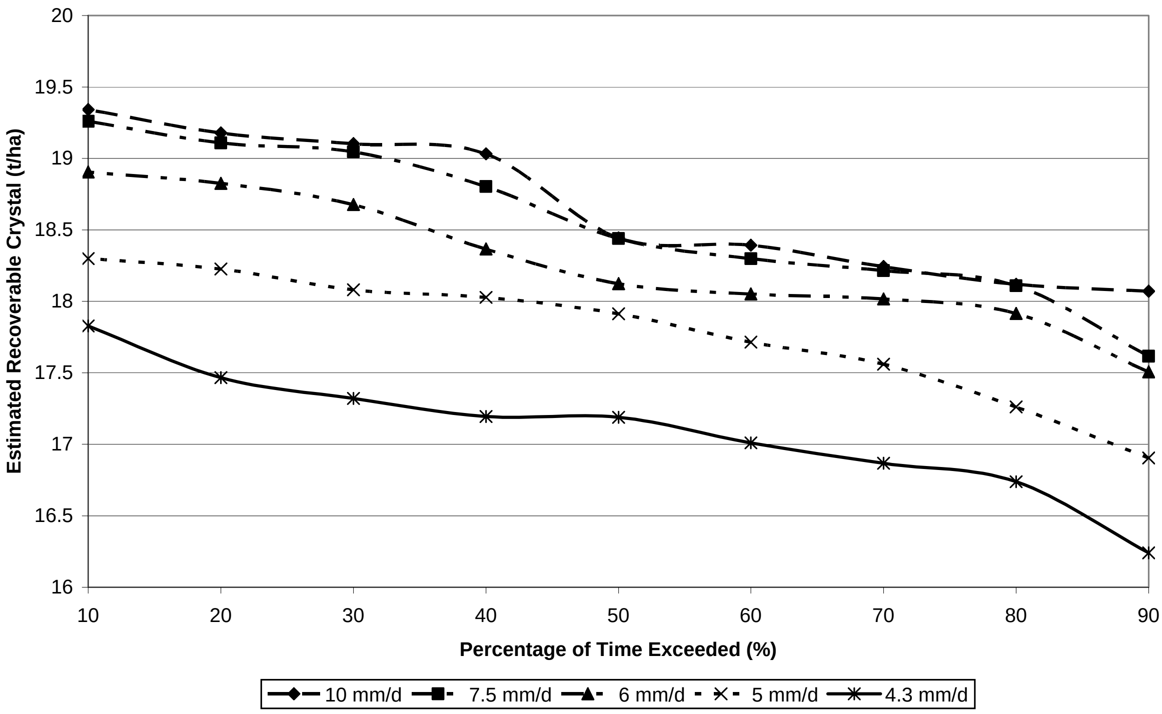

Figure 1. Cumulative frequency distributions of yields of estimated recoverable crystal for various peak irrigation system capacities.

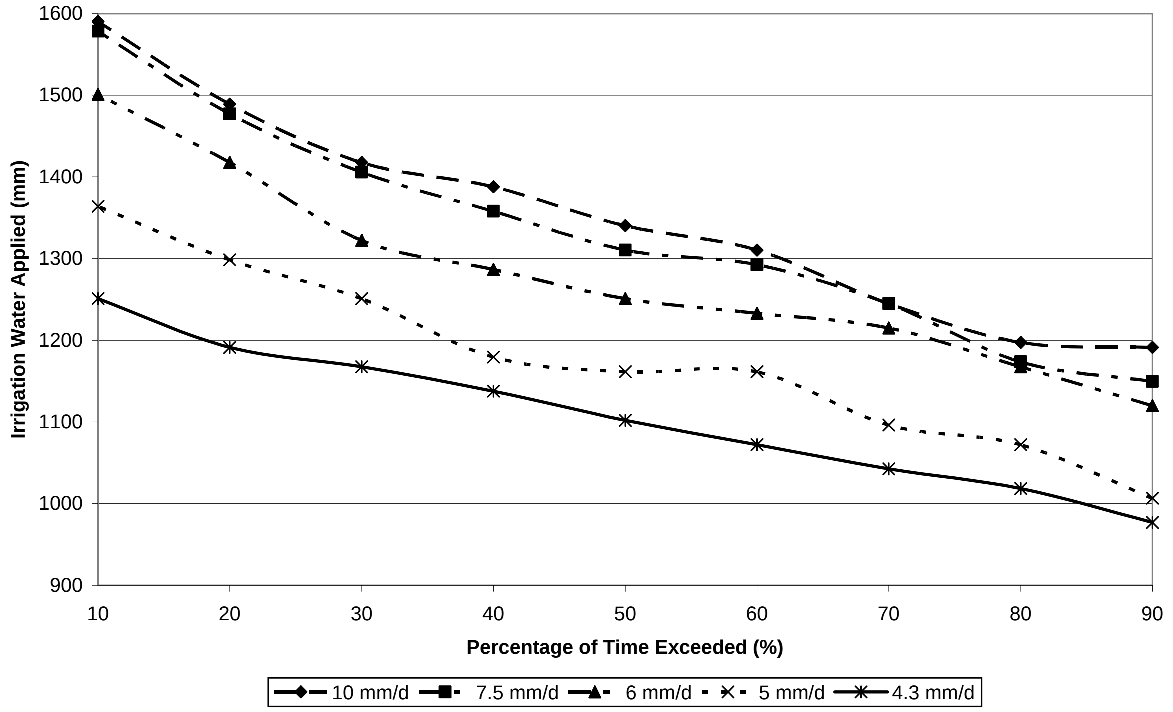

Figure 2. Cumulative frequency distributions of seasonal irrigation water applications for various peak irrigation system capacities.

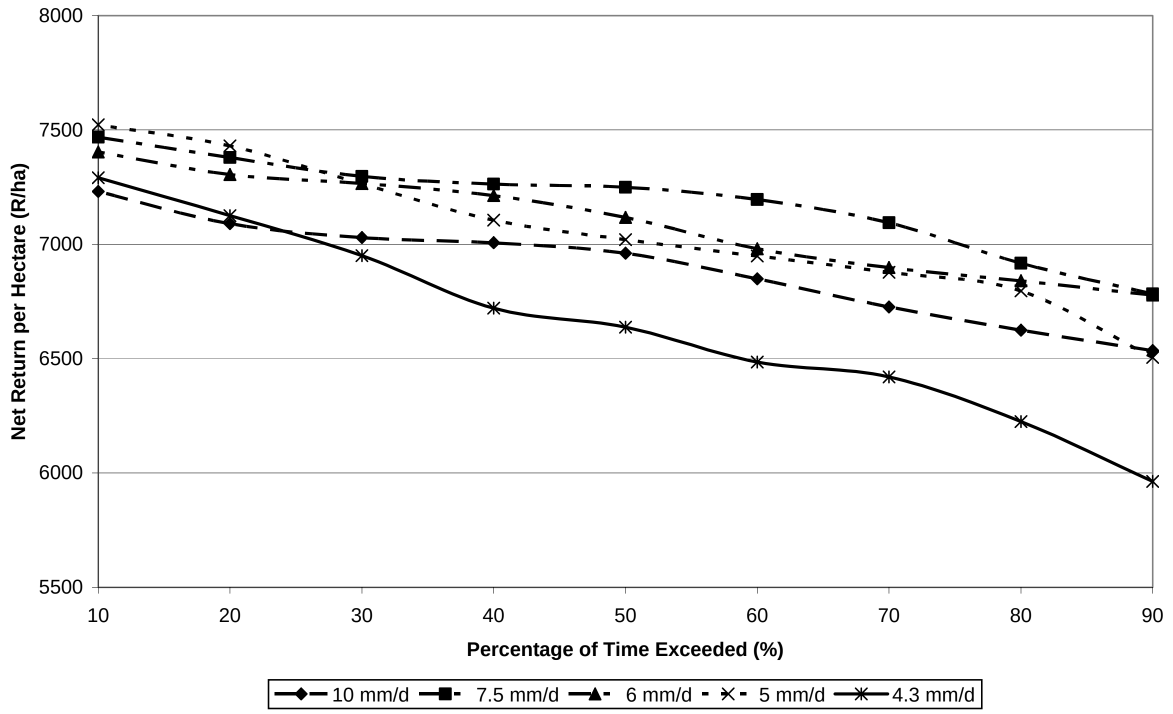

Figure 3. Cumulative frequency distributions of net returns per hectare for various peak irrigation system capacities.

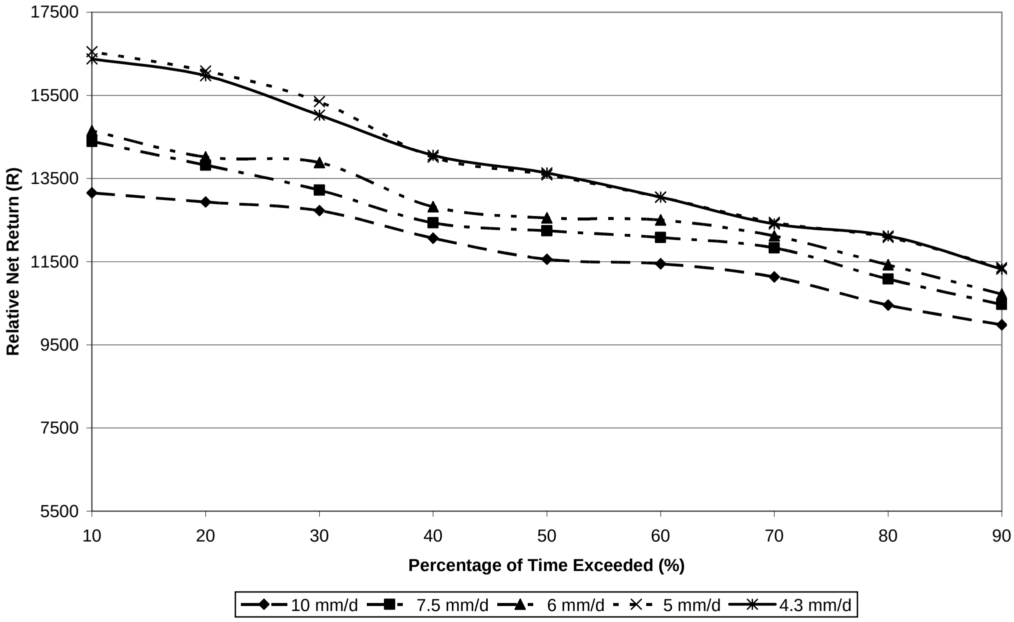

Figure.4. Cumulative frequency distributions of relative net returns per hectare (net return per hectare x relative irrigable area) for various peak irrigation system capacities.

Discussion and Conclusions

Examination of the results in Figures 1 and 2 shows that:

- the peak irrigation system capacity had a considerable effect on the total amount of irrigation water applied in a season (Figure 2)
- the potential yield which could be obtained was dependent on the system capacity limitations (Figure 1)
- the marginal yield benefits decreased as the system capacities increased (Figure 1)
- increasing the system capacity beyond a certain limit resulted in minimal further crop yield benefits, illustrated by a comparison of the water used and yields attained for systems with capacity limitations of 10 mm/d and 7.5 mm/d (Figure 1 and Figure 2)
- correct irrigation scheduling is important, as indicated in the range of seasonal irrigation water applications for a given system capacity (Figure 2)
- correct irrigation scheduling becomes more and more important with increasing system capacity as the range in water applied becomes larger and the potential for wastage greater (Figure 2).

The system with the highest capacity of 10 mm/d gave the best yields of ERC (cf. Figure 1), however, from an economic perspective, this was not the best system. If availability of land limited production (relative to available water) then the system with a capacity equivalent to 7.5 mm/d was estimated to give the best overall returns (cf. Figure 3). However, if water was the factor which limited production (relative to available land), then the system with a capacity of only 5 mm/d (cf. Figure 4), gave the best overall profitability. This case study application highlights the potential benefits of deficit irrigation, especially under water limited production conditions, and also the value of using simulation models to inform the design process.

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