SHORT COMMUNICATION

A CATCHMENT SCALE IRRIGATION SYSTEMS MODEL FOR SUGARCANE

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Abstract

In South Africa, the demand for water exceeds available supplies in many catchment areas. As a result, farmers face increasing pressure to use water more effectively, to justify existing water requirements and to budget and plan with growing uncertainty regarding water availability. Therefore, a tool to manage and assess catchment water supply and demand interactions and the associated impacts on the profitability of irrigated sugarcane would be of great value. In this communication the development of such a catchment scale irrigation systems modelling tool is described. The model has application for testing and assessing various operating, water allocation, water management and water resources development strategies. The tool is also designed to predict the expected performance of different types of irrigation system hardware.

Keywords: irrigation systems, water management, modelling, hydrology, water resources, sugarcane

Introduction

In South Africa, the demand for water exceeds available supplies in many catchment areas. Since a substantial amount of water is assigned to irrigated agriculture, farmers face increasing pressure to use water more effectively and to justify existing water usage. In order to justify existing water requirements and to budget and plan in the context of growing uncertainty regarding water availability, a tool to assist in the assessment and management of catchment water supply and demand interactions and the associated impacts on the profitability of irrigated sugarcane is needed.

While there have been many useful model developments for sugarcane and water resources management, none of these provide all the necessary decision support information in an integrated fashion. Therefore, the development of a catchment scale irrigation system model, as described in this short communication, was initiated.

Methodology

In order to distil the concepts best suited for the development of the tool required, in-field evaluations of irrigation systems were undertaken with a mobile irrigation laboratory (MIL) and a review of appropriate literature and models was conducted. Ascough and Lecler (2004) reported on an analysis of the results from the MIL evaluations and highlighted, amongst others, the importance of water supply and demand interactions on the performance of irrigation and water management systems. In the review of models and literature, the following models were appraised: SWB (Campbell and Diaz, 1988). CANEGRO (Inman-Bamber, 1991), *ACRU* (Schulze, 1995), APSIM (McCown *et al*, 1996), CANESIM (Singels *et al*, 1998) and *ZIMsched* 2.0 (Lecler, 2003). The FAO Irrigation and Drainage Paper No. 56 (Allen *et al.*, 1998) was also reviewed as it is fundamental to the water budget used in *ZIMsched* 2.0 and SWB. A conclusion of the review process was that despite their respective strengths, none of these models and associated algorithms incorporated all the desired system processes, outlined below, in an integrated fashion.

The *ACRU* model is a catchment scale agrohydrological model capable of simulating many different water supply or availability scenarios. Consequently, the *ACRU* model was used to form the water supply link with a smaller sub-model, ACRU*Cane*, developed to simulate the water budget of an irrigated field of sugarcane and the associated sucrose yields associated with different types of irrigation systems.

The water budget in ACRU*Cane* is based primarily on a unique integration and refinement of robust algorithms from FAO 56 (Allen *et al,* 1998) and the *ACRU* model (Schulze, 1995), such that the following processes are represented:

- evaporation from the soil surface and transpiration in relation to:
    - atmospheric evaporative demand
    - available soil water, including excess and/or deficient conditions
    - crop and rooting characteristics, the development of which are related to temperature and thermal time
    - irrigation system type, for example, sub-surface drip irrigation versus overhead sprinkler irrigation
- stormflow (surface runoff)
- deep percolation

all of which relate to

- rainfall effectiveness
- sucrose yields
- irrigation return flows to the catchment.

The algorithms representing these processes are described in detail by Lecler (2003, 2004).

Different types of irrigation system hardware are accounted for in several ways in ACRU*Cane*. The irrigation system type, for example 'drip' irrigation, is associated with system specific attributes such as the fraction of soil wetted by irrigation, and whether or not interception of irrigation water applications occurs. Included in the required input parameter set is an irrigation uniformity index such as the Distribution Uniformity, DU, to enable the simulation of non-uniform irrigation water applications which occur in practice. This is achieved using multiple water budgets and assuming a normal distribution of irrigation depths as described by Lecler (2003) and Ascough and Lecler (2004a). Associated impacts of water management are represented through the simulation of a wide range of irrigation scheduling options.

To estimate associated yields of sucrose, an algorithm developed by Doorenbos and Kassam (1979) and modified by De Jager (1994), is used in ACRU*Cane* (cf. Equation 1).

$$Y_a/Y_p = \Sigma(1 - K_{yi}(1 - E_t/E_{tm})) \qquad \text{….Eq.1}$$

Where Y_a = Actual yield (t/ha)

Y_p = Potential yield (t/ha)
K_{yi} = yield response factor for the ith growth period
E_t = Simulated actual transpiration (mm)
E_{tm} = Simulated maximum transpiration, i.e. with no soil water stress (mm).

Thus with an estimate of the potential sucrose yield it is possible to determine the actual yield by accounting for the impacts of water stress via the ratio of actual to potential transpiration at different times in the growth cycle. The potential sucrose yield is obtained using a modified version of the relationship derived by Thompson (1976) as described by Lecler (2003). A second, radiation based, biomass accumulation yield model developed by Singels and Bezuidenhout (2002) for CANEGRO is also being considered for incorporation into ACRU*Cane*.

A variety of water supply options can be simulated by ACRU*Cane* through the ACRU model. These options are shown in Figure 1. The user can thus quantify the impact of different water supply options and constraints on the water budget and ultimately the yield of an irrigated sugarcane crop.

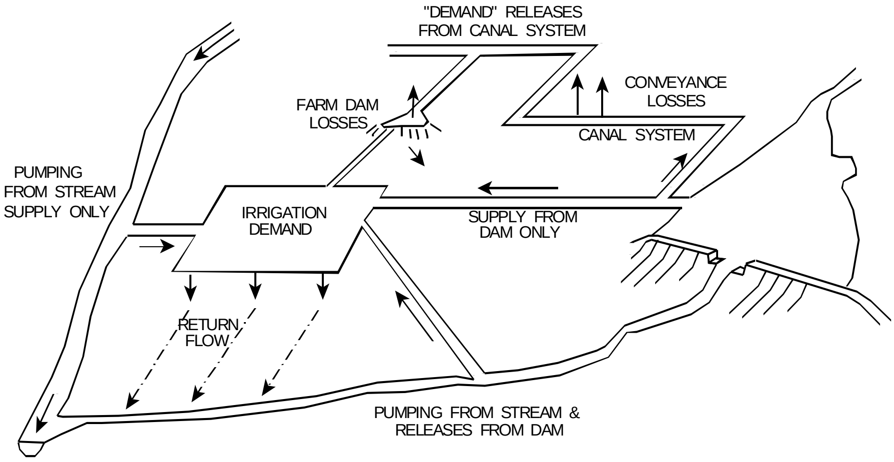

Figure 1. Schematic diagram of supply options available in ACRU (after Schulze, 1995).

Conclusions

A core objective of this project was to form a 'link' between predicted crop water requirements, sucrose yields and the availability of water from a catchment, i.e. from a dam or directly from a river. Furthermore, these predictions needed to be representative of various water management and irrigation system hardware alternatives. These objectives have been achieved in principle but because ACRU*Cane* is currently being verified, no results of its application are available as yet. ACRU*Cane* has the potential to provide management advice to a wide range of users. It should enable the expected performance of different types of irrigation and water management systems to be investigated. Furthermore, all of these can be assessed in relation to risks associated with available water supplies, water allocations and allocation systems providing information needed to assess the potential profitability of various alternatives. In terms of water resources assessments ACRU*Cane* could be used to determine impacts of a given area of irrigated sugarcane on water availability or *vice-versa*, for a range of irrigation systems and water management scenarios.

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