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Integrating soil water monitoring technology and weather based crop modelling to provide improved decision support for sugarcane irrigation management

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ABSTRACT

Various technologies exist to support scientific irrigation scheduling, each with its own strengths and weaknesses. Weather-based crop models are good at estimating evapotranspiration and future irrigation needs over large areas, while electronic soil water sensors are able to provide good estimates of soil water status at a given point. Synergy may be obtained by combining these technologies to enhance their usefulness for irrigation management. The objective of this study was to incorporate real-time field records of soil water status into a weather based sugarcane simulation system and to evaluate its use for supporting irrigation scheduling in 15 sugarcane fields in South Africa.

Layered soil water status data from capacitance probes were converted to root zone available soil water content (ASWC) using linear scaling. Field specific calibration coefficients were derived from drainage and extraction patterns.

An analysis of simulation outputs and observed cane yields suggested that yields were substantially below potential for seven out of the 15 fields. Two fields had prolonged periods of water stress due to under-irrigation, as reflected by the fact that yields from simulations based on measured soil water data were substantially below the potential yield. Yields in six fields were probably limited by poor husbandry as suggested by the fact that observed yields were well below simulated yields using measured soil water data.

The system was demonstrated to commercial and small-scale farmers and extension officers during a series of workshops. The integrated system provides enhanced support for irrigation water management for sugarcane production. Farmers and extension specialists can understand the impact of irrigation practices on the soil water regime and its impact on crop growth and yield. This is a good basis for making adjustments to irrigation practices and for benchmarking crop performance and water use efficiency. It also has value for supporting irrigation scheduling decisions.

1. Introduction

Effective irrigation scheduling is important for optimizing the use of irrigation water for sugarcane production globally. Optimal use of water is required to maximize profitability and minimize negative impacts on the environment. Various technologies exist to support scientific irrigation scheduling, each with its own strengths and weaknesses. Weather-based crop models are good at estimating evapotranspiration (ET) and future irrigation needs over large areas (Akyüz et al., 2008; Busch et al., 2009; Inman-Bamber et al., 2005; Thysen and Detlefsen, 2006) while electronic soil water sensors are able to provide good estimates of soil water status at a given point (Farina and Bacci, 2005), provided sensor output is appropriately interpreted (Paige and Keefer, 2008). Synergy can be obtained by combining these technologies to enhance their usefulness for irrigation management because the predictive power of weather-based models (e.g. the ability to forecast irrigation requirements and yield) can be combined with the accuracy of field based sensors for estimating soil water status. Holloway-Phillips et al. (2008) proposed a framework for "fusing" soil water models and in situ soil water sensors to predict soil water extraction and the date of the next irrigation. Real time data from sensors could be used to "enhance or calibrate" simulations of the soil water balance to support irrigation management (Holloway-Phillips et al., 2008).

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The Soil Water Balance (SWB) crop model system developed by Annandale et al. (2005) has the capability to store measured soil water data in its database for comparison with simulated values. Neutron water meter data or converted volumetric soil water data can be uploaded manually into the SWB database and can be used to correct the simulated soil water content. Thomson and Ross (1996) developed a system to use data from soil water potential sensors to adjust soil water balance parameters in a crop model for scheduling irrigation in peanuts. Sensor data were fed manually into the modelling database and used to automatically adjust soil and rooting parameters in order to improve the accuracy of soil water balance simulations and irrigation advice. Integration of soil water monitoring and weather based modelling can be more useful if human intervention is kept to a minimum. Modern sensor and transmission technology allows soil water data from remote sites to be available near real time and this should be utilized. Soil water data processing to ensure compatibility with simulation systems and data integration should be automated as far as possible. The option to correct simulations with soil water records will enhance the relevance and accuracy of irrigation advice and estimates of crop performance (e.g. yield).

The MyCanesim® sugarcane modelling and irrigation scheduling system (Singels, 2007) simulates the daily soil water balance taking into account ET, rainfall, irrigation, drainage and runoff. Soil water status is quantified as the amount of water in the root zone available to the plant (ASWC, mm). Irrigation scheduling is triggered when ASWC approaches a user specified depletion level (ADL, mm) and the specified irrigation cycle limitation is satisfied. Scheduling advice is provided in the form of text messages, email, fax and website reports.

MyCanesim® was first used in May 2005 to provide real-time irrigation scheduling advice to a group of small-scale farmers in Pongola, Kwazulu-Natal (Singels and Smith, 2006) By 2007, the service was extended to 47 farmers (Singels and Smith, 2008). A drawback of the service is that if irrigation advice is not followed precisely (applying the assumed amount on the recommended date), the simulated ASWC can deviate from actual values in the field, leading to incorrect advice. A potential solution is to use recorded soil water content with appropriate technology to correct simulations.

The objective of the study was to incorporate near real-time field recordings of soil water content into the MyCanesim® system and to evaluate its use for supporting irrigation management in 15 sugarcane fields in the Mpumalanga and Kwazulu-Natal provinces of South Africa. The value of correcting simulated ASWC for reviewing irrigation practices and for guiding irrigation scheduling, were assessed with participating farmers. The system was also used to assess irrigation and agronomic management on these fields using simulated and observed data.

2. System development

The MyCanesim® system is described by (Singels, 2007) and Singels and Smith (2006). Briefly, it consists of the Canesim® sugarcane simulation model linked to an on-line weather and field database, and an irrigation scheduling and advice module. The system uses basic field data (e.g. soil water holding capacity, cropping details and irrigation system properties), initially entered by the user via a web-based interface, to calculate the soil and crop status for each day of the growing season. The model has a single layer soil water balance (see Singels et al., 1998 for a full description) and simulates crop transpiration, evaporation from the soil, deep drainage and run-off. Redistribution of water within the root zone is not simulated. All water within the root zone is considered available to plants throughout the growing cycle, reflecting the rapid establishment of roots in irrigated ratoon crops. Crop canopy cover is calculated from thermal time (Singels and Donaldson, 2000) and crop water status (Singels et al., 2008). Canopy cover is used to calculate interception of solar radiation that drives potential transpiration and biomass accumulation. Actual transpiration and biomass accumulation is determined by potential rates and crop water status, which depends on soil water status (Singels et al., 2010). Daily biomass accumulated is partitioned to stalk fibre and sucrose following the method of Singels and Bezuidenhout (2002). The system can be used to analyse agronomic performance of past seasons or to predict water use, irrigation requirements and yields for the current season.

The following aspects of the system will now be described in more detail:

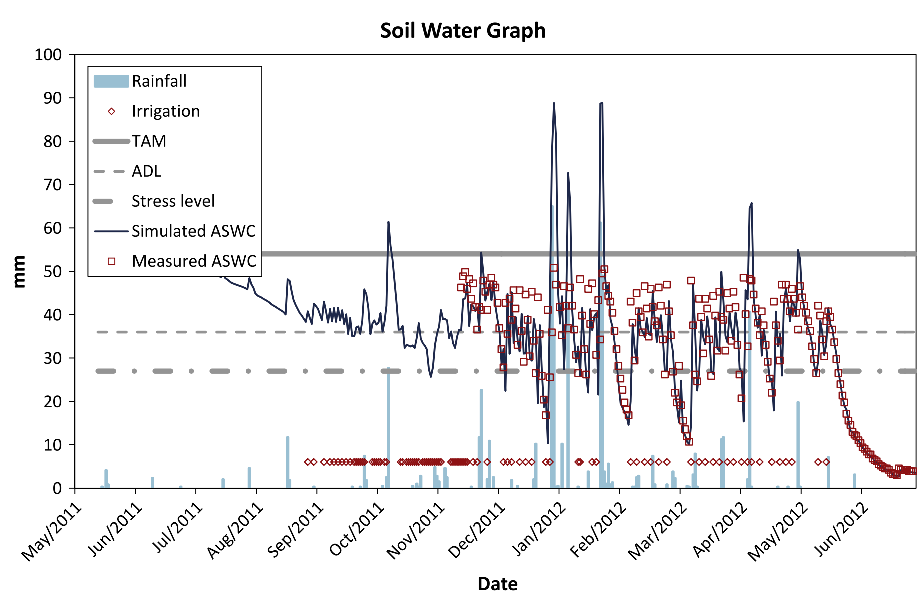

Fig. 1. An example of MyCanesim® output: Daily values of simulated (blue line) and measured (red open squares) root zone available soil water content (ASWC), rainfall (blue bars) and irrigation (red open circles). The horizontal solid line indicates the ASWC at field capacity (TAM), the line with small dashes indicates the chosen allowable depletion level (ADL), and the line with mixed dashes represents Canesim®'s stress point. In this specific example simulated ASWC was corrected with measured values. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)