Toward Real-Time Control and Management of Surface Irrigation

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INTRODUCTION

Surface irrigation, especially furrow irrigation, is one of the most commonly used methods for irrigating crops and pastures in Australia and around the world. Well-designed and managed surface irrigation systems can have application efficiencies of up to 95%. But many commercial systems have been found to be operating with lower and highly variable efficiencies. For example, in sugar and cotton application efficiencies for individual irrigations range from 14 to 90% and average efficiencies over the season range from 31 and 62% (Raine and Bakker 1996; Smith et al. 2005).

The application efficiencies of surface irrigation are a function of the field design, infiltration characteristic and the irrigation management practice. Once a crop is established the soil infiltration characteristic is the most crucial factor affecting application efficiency. Thus we need to know what the infiltration rate is so that irrigation cut-off times can be set when irrigation events are underway to improve application efficiencies.

Real-time control of surface irrigation involves using infiltration information from the current irrigation event to set the cut-off time. This would allow considerable water savings to be made by reducing run-off and deep drainage losses. The problem is that firstly, infiltration varies across the field and over time, and secondly that infiltration estimation methods are data intensive and hence information on which to make irrigation decisions is not available until after the event.

In this paper we outline a model infiltration curve and a scaling technique (REIP) developed by Khatri and Smith (2006). The method requires minimum field data, inflow and only one advance point measured around the mid length of the furrow. The success of this method opens the door to real-time control of surface irrigation systems and the resultant increase in application efficiency with substantial reductions in volume of water applied.

DESCRIPTION OF THE PROPOSED SYSTEM

The basis of the system is a new method REIP (Real-time Estimation of Infiltration Parameters) for predicting the soil infiltration characteristics for individual furrows. The REIP method requires minimum field data, inflow and only one advance point measured around the mid length of the furrow. Using one advance point results in huge savings in labor and equipment costs and substantial reductions in data acquisition burden on the part of irrigators and enables the implementation of real time control. The underlying hypothesis for the method is that the ***shape*** of the infiltration characteristic for a particular field or soil is relatively constant (across the field and with time), despite variations in the magnitude of the infiltration rate or amount.

A typical furrow in the field is selected for evaluation (known as the model furrow) and its infiltration parameters (a, k, f_o) in the Kostiakov–Lewis equation:

$$I = kt^a + f_o t$$

are determined by a model such as INFILT (McClymont and Smith, 1996) using inflow and extensive advance data. Subsequently the infiltration parameters for this model furrow can be scaled to give the cumulative infiltration curves for the whole field. In this process a scaling factor *(F)* is formulated from rearrangement of the volume balance equation and is calculated for each furrow/event using the model infiltration parameters and the single advance point. The performance of each furrow can then be simulated and optimised using an appropriate simulation model like SIRMOD (Walker, 2001) to determine the preferred time to cut-off. SIRMOD is a software package designed to simulate the hydraulics of surface irrigation at the furrow scale, and to optimize the irrigation system parameters to maximize application efficiency. The input data required for the simulation component of the model include field length, slope, infiltration characteristics, target application depth, flow rate, Manning *n* and furrow geometry. The model output includes a detailed advance-recession trajectory, distribution of infiltrated water, runoff hydrograph, water distribution uniformity, and the water application and requirement efficiencies. The ability of the SIRMOD to evaluate the irrigation performance of furrows and borders has been well documented (for example, McClymont *et al.*, 1996).

EVALUATION

To evaluate the REIP method, two cotton fields (T & C) were selected, from which irrigation water balance and advance data were available for a total of 42 furrow irrigation events. A furrow was selected as the model furrow for each field, and the REIP method as described above was applied. The actual irrigations for each furrow were simulated using the simulation model SIRMOD (Walker, 2001) to give the performance parameters (application efficiency, requirement efficiency and uniformity) for those irrigations. SIRMOD was then used with the scaled infiltration parameters to assess the performance of the real time control.

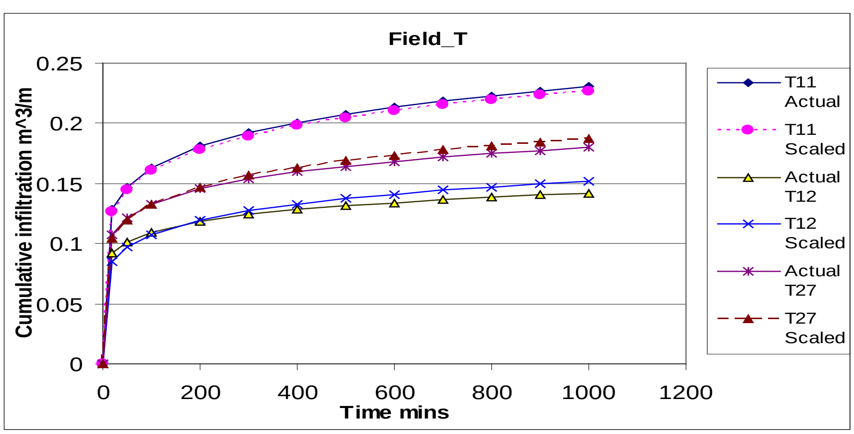

Figure 1. Example of scaled and actual infiltration curves from field T only. Analysis was based on a total of 42 infiltration relationships.

The results revealed that the infiltration curves produced by proposed method were of similar shape (Figure 1) and hence gave a distribution of cumulative depths of infiltration for the whole field that was statistically equivalent to that given using the complete set of advance data for each furrow. The advance trajectories produced by the proposed method also matched (Figure 2) favourably to the measured advances.

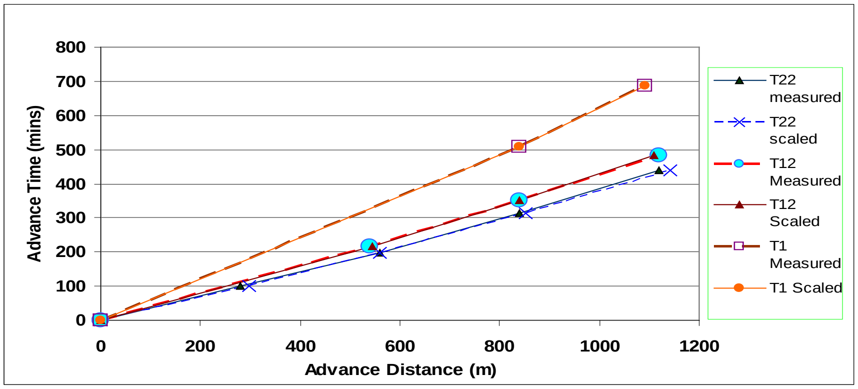

Figure 2. Example of measured and predicted water advance along the length of furrow (It is interesting to note here that predicted advance using only one point is almost identical to actual measured advance which clearly establishes the suitability of new method)

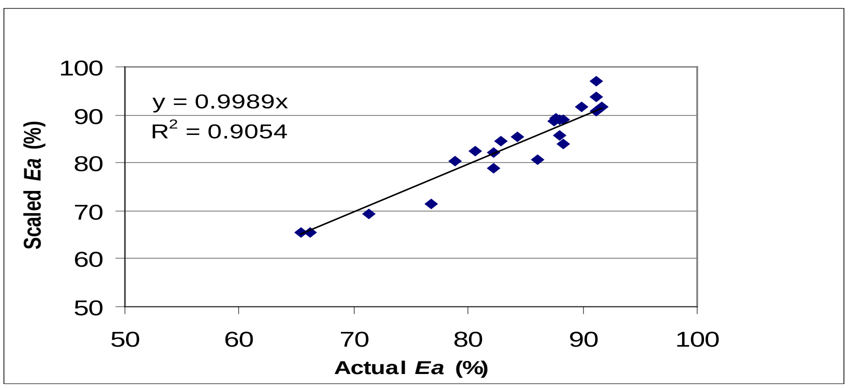

Figure 3. Comparison of irrigation performance results (application efficiencies) under model strategies 5(Using full set of data) and 6(Using only one advance point by REIP) for a cotton field T

The simulation results showed that the scaled infiltration gave predictions of the irrigation performance almost similar to the actual performance as shown in comparison of application efficiencies (Figure 3). They also indicated that by adopting the REIP method a simple real time control system (which determines cut-off times) would have increased irrigation application efficiencies from 76% and 38%, to 85% and 72% for the fields T & C, respectively.

This would have saved 20% and 60% of water applied to fields T & C, respectively and reduced deep drainage and run-off losses. Across the two fields this indicates a seasonal saving of 2.02 ML per ha of the cotton grown, which represents a significant amount of water savings that can be used beneficially to grow greater crop area.

CONCLUSIONS

Real-time control of surface irrigation systems has the potential to considerably improve application efficiencies. This produces benefits on-farm via increases in water productivity and decreases in deep drainage losses thus reducing the risk of waterlogging and salinity.

The REIP method proved successful in estimating infiltration based on inflow and one advance point measurement in a single furrow without significant loss of accuracy. This was the case in two fields with contrasting infiltration characteristics. The scaling techniques combined with the reduction in data requirements opens the door for the REIP system to be used in the field to provide real-time control of surface irrigation events. In the past this was not possible because determining infiltration rates was data intensive and hence expensive and could not be estimated to after the irrigation event was completed.

In this example use of real-time control of the irrigation event would have resulted in water savings of 2.02 ML/ha across the two fields. This would have been achieved by using the REIP method to estimate field infiltration rates and set cut-off times during the actual irrigation event. The end result is that application efficiency is improved, increasing water productivity and, decreasing off-farm impacts by reducing deep drainage and surface run-off.

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