SWAGMAN? DESTINY: A TOOL TO PROJECT PRODUCTIVITY CHANGE DUE TO SALINITY, WATERLOGGING AND IRRIGATION MANAGEMENT

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Summary. Salinisation of the root zone is the result of interaction between salt loading from surface additions and groundwater conditions affecting salt and water fluxes at the lower boundary of the root zone. Many irrigation areas, where shallow water tables have developed, require management strategies which maintain productivity in the face of potentially increasing salinity. SWAGMAN? Destiny is a point scale salt and water balance model which can be used to estimate change in crop yield resulting from water table and salt interactions. The model uses fairly readily available soil profile data, together with daily weather data to calculate salt and water balances. The simulated crop responds to stresses from water shortage, aeration, salt and nitrogen shortage. Application of the model to an irrigated perennial pasture situation in northern Victoria shows the strong interaction between irrigation water salt concentration and the long term water table level set by the prevailing groundwater conditions. Management of irrigation can influence this interaction but only within a limited range.

INTRODUCTION

Within the Murray-Darling Basin of Australia 150,000 ha of irrigated land has a water table within 2 m of the surface (4). If present recharge rates are maintained this area is likely to double within the next 30 to 40 years. With water tables so close to the ground surface the soil profile is predisposed to increasing salinisation since the rate of salt accumulation is likely to exceed the rate of profile leaching. The basic processes causing salinisation in irrigation and dryland areas are the same. In dryland areas salt accumulation is due to the enhanced upflow into the unsaturated root zone from local or regional groundwaters. This also occurs in irrigation areas but the additional salt load associated with irrigation water compounds the problem when leaching is restricted by the presence of a water table. The question then is, how can we maintain productivity into the future where water tables are rising or where they are close to the ground surface? This question is faced by many land and water management planning groups. Providing reliable forward estimates is difficult because of the complexity of the climatic, hydrogeologic and management factors which can change the rate of water table movement and rate of salt accumulation. SWAGMAN? Destiny is a point scale model designed to estimate the salt and water balances and to estimate change in crop yield resulting from these root zone conditions.

MODEL DESCRIPTION

The model has evolved from the SWAGMAN? Whatif program (3) and from experience with the CERES models of crop growth (2). It is one dimensional (point scale) and estimates water and salt balances in response to crop agronomy, irrigation management and daily weather conditions. Operationally it has three interlinked components

(1) the soil water and crop growth simulation model,

(2) a data base of soil, weather, crop and economic parameters,

(3) a shell program which controls all simulation set up, access to the data bases, graphics and analysis programs.

Simulation modes

The package has three modes of operation. A *continuous detailed mode* which is most commonly used for model testing with observed data. The second *strategic mode* where the user can select five scenarios associated with a particular variable. These variables include crop type, soil type, water table level, the salinity of the soil and irrigation water. The third *continuous multi-year mode* examines the consequences of maintaining a particular strategy year-after-year. In this mode, not only are the trends in water table levels, salinity levels and yield estimated but the variability in these values caused by season-to-season weather variability is also indicated.

Crop growth and development

A generic model is used in Destiny to provide estimated growth and development for a range of crops from annual agronomic, to perennial pasture to perennial horticulture. Daily growth is influenced by the amount of radiant energy captured by the canopy, temperature and the prevailing stresses. Biomass is apportioned to roots and distributed throughout the profile according to which soil layers are most favourable for root growth. Stresses from water shortage, aeration, salinity and nitrogen are used to limit growth processes and to enhance senescence. During each day of simulation, the balances of water and salt are determined, and zero to unity indices of stress for each of the factors above are calculated. The most limiting of these indices is used as the scalar of each day's potential growth.

Hydrological components

The model simulates the water and salt balances in a 5 m deep soil profile (Fig. 1). The fluxes at the ground surface and at the bottom layer soil boundary are considered. Infiltration into the profile uses a time to ponding approach modified after Broadbridge and White (1). Drainage down through soil layers uses a simple cascading, or modified tipping bucket concept. Inputs needed to specify the soil include, lower limit, drained upper limit and saturated volumetric water content. Upflow (unsaturated flow) from wet soil layers to drier layers is determined from an internally calculated diffusivity gradient.

A water table will exist in the soil when the conductivity of a layer is less than the rate that water can potentially move into it. In Destiny, the depth from the ground surface to the water table is determined from the bottom of the profile upward. The extent of drainable water, draining at a rate consistent with that draining from the lowermost layer constitutes a contiguous water table.

From an initial soil salinity profile (in dS/m), salt is moved with water movement to preserve mass balance. As water moves towards the surface with evaporative flux, some salt is transported upwards. Salt present in the surface layer can equilibrate with any ponded water and may be lost from the profile by runoff.

Potential evaporation, determined internally from daily weather data is partitioned between plant evaporation and ground surface evaporation. This partitioning is done on the basis of leaf area.

MODEL TESTING

Only limited testing has been done thus far. Comparisons with water balance components from lysimeter measurements are generally satisfactory. Evaporation from irrigated annual crops was estimated with an error of less than 50 mm per annum. Upflow estimates were consistent with measured values although further testing and detailed analysis of estimated and measured soil water content changes are required.

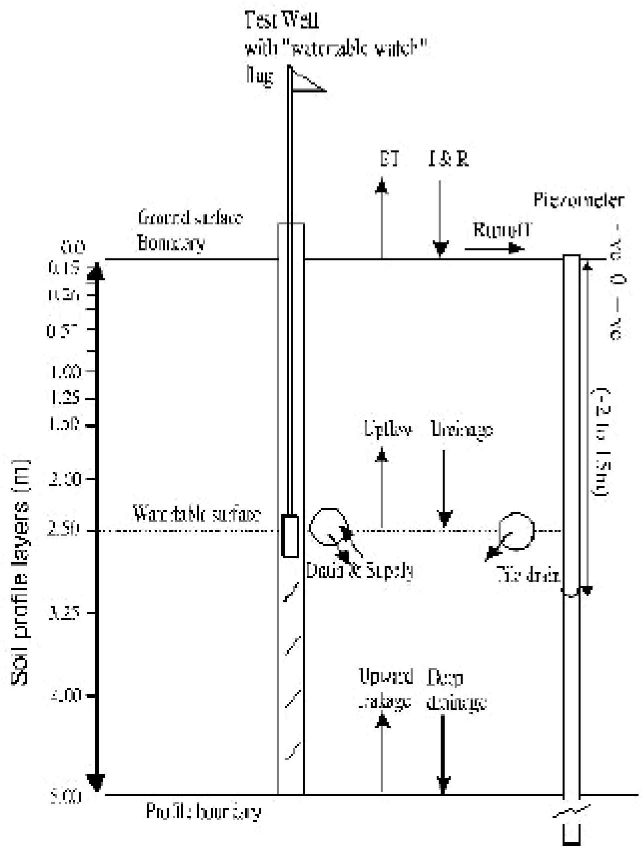


Figure 1. Schematic diagram of the major components in the water balance of SWAGMAN Destiny. The soil layer depth increments are shown on the vertical axis.

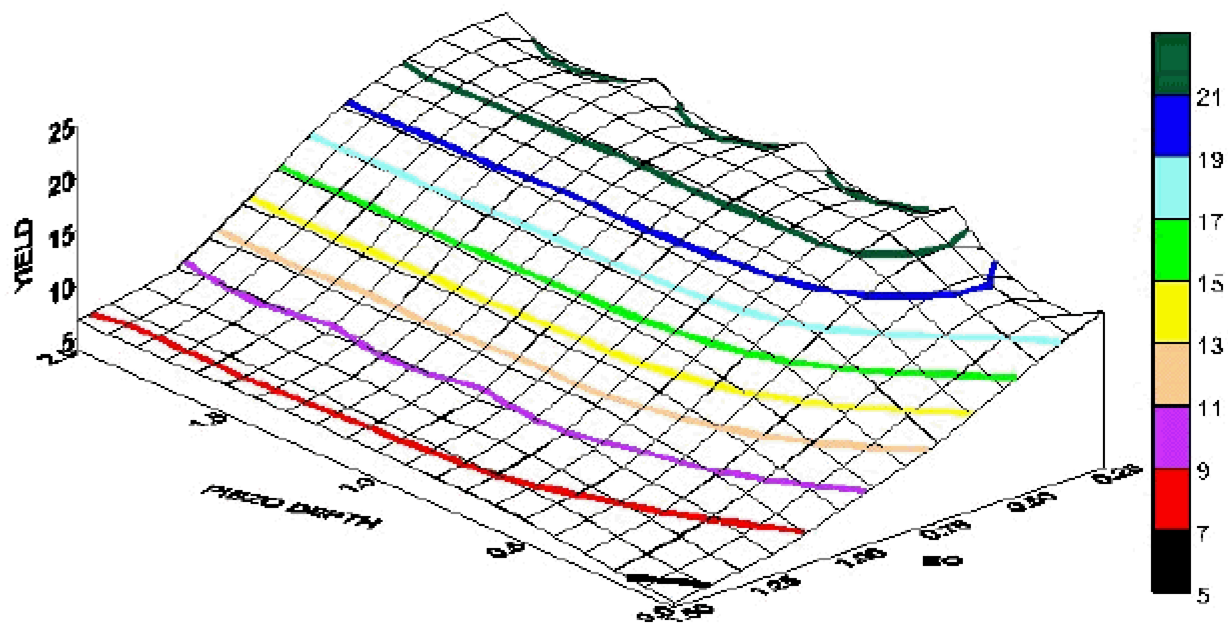
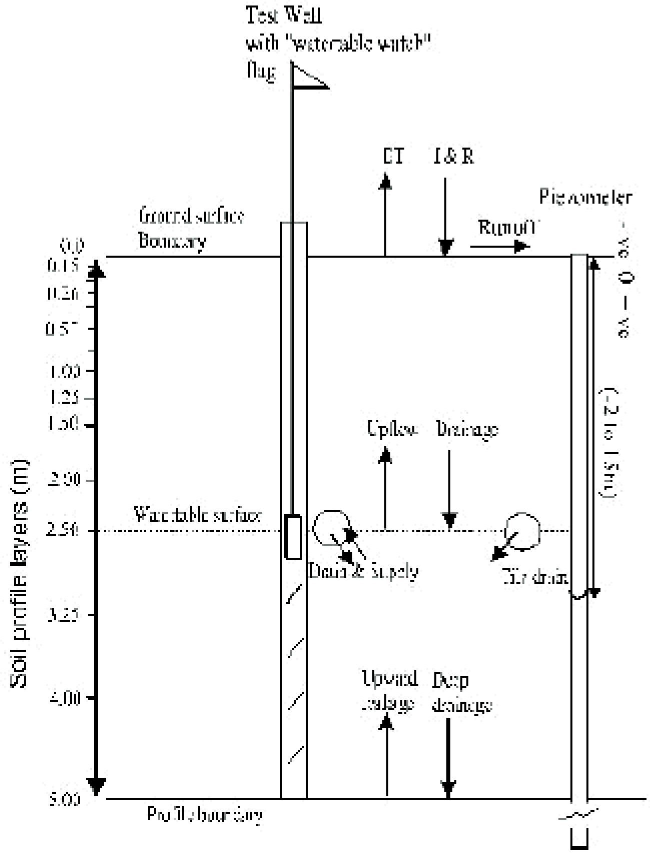


Figure 2. Yield response surface for irrigated perennial pasture in northern Victoria. EC is the electrical conductivity fo the irrigation water (dS m) and piezo depth is the depth from the ground surface (m) to the long term groundwater level.



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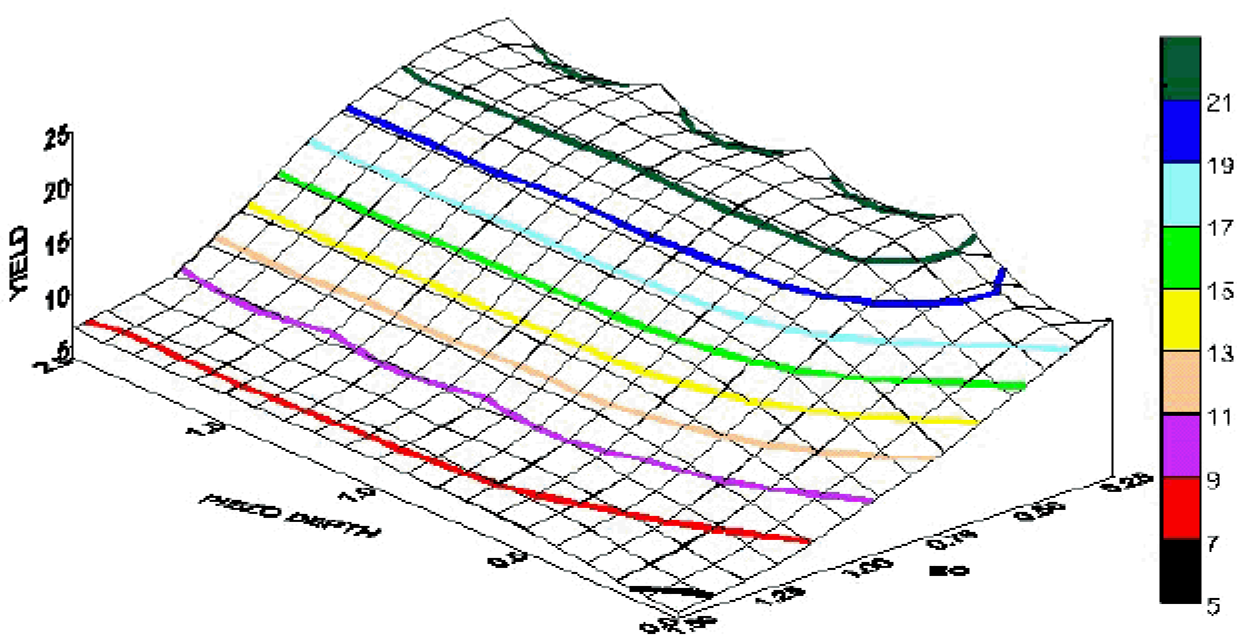

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MODEL APPLICATION

SWAGMAN? Destiny has been used to analyse several intensively monitored sites in an irrigated pasture area near Cohuna in north central Victoria. The depth from the ground surface to the water table was monitored continuously and varied from 1.8 m to the surface depending on the position in the landscape and irrigation management. Destiny was able to simulate fluctuations in the water table level, although the range of the estimated fluctuations was less than observed.

At one site, the model estimated a net drainage rate of 95 mm per year. This was a non salinised profile within 50 m of a reasonably deep surface drain. At another site, the long term water table level was about 0.8 m below the surface. Destiny estimated a drainage rate of about 40 mm and an upflow of 8 mm per year. Longer term simulations indicated that productivity at this site could be maintained if irrigation and groundwater conditions remained as they currently are. At a more salinised site annual drainage was 11 mm while upflow was 42 mm. From a groundwater perspective, annual recharge was 11 mm, annual discharge with the long term water table at 0.3 m was 42 mm. With groundwater salinity of 18 dS/m it is highly likely that the profile will remain saline, and probably increasingly saline if current conditions prevail.

Destiny has been used to estimate the longer term (10-20 years) change in yield. It has become apparent that the interaction between irrigation water additions and the long term water table level (set by the interconnected groundwater piezometric pressure level) is paramount. This interaction is shown in Fig. 2. In essence, this yield response surface primarily reflects the effective salinity of the root zone after 10 years of perennial pasture. The secondary effect of waterlogging during winter will also be influential. Clearly there can be some tradeoff between irrigation water quality (and therefore salt loading from the surface) and the depth to the water table. However, the management flexibility available to avoid yield decrements is quite small. It is expected that the shape and position of the yield response surface will change with crop type, irrigation management, groundwater salinity and conditions affecting the groundwater fluxes at the lower boundary of the soil profile.

REFERENCES

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