MULTISCALE ENVIRONMENTAL SUSTAINABILITY MODELLING IN LARGE IRRIGATION SYSTEMS

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Introduction

Unsustainable land and water management practices that violate the system’s carrying capacity constraint over long periods can impose significant costs in terms of lost opportunities in farm production and regional development, say by causing waterlogging and salinity. In fact, the productivity of major irrigation areas in the semi arid and arid regions of the world is facing challenges of waterlogging and secondary salinisation of landscapes (Ghassemi et al., 1995). It is estimated that more than 60 million ha or 24% of the all the irrigated land is salinised (World Bank, 1992). A small fraction of deep percolation (leaching fraction) under crops is necessary to leach out excess salts from the root zone to maintain productivity (Hoffman, 1990). Excessive irrigation of crops, seepage losses from channels and storages result in groundwater recharge to the unconfined aquifers (Rushton, 1999). If the groundwater recharge is greater than the groundwater leakage to the deeper aquifers and lateral regional groundwater flow, the watertables will start rising. When the watertable is less than 2 m from the soil surface, the root zone of the plants becomes restricted and capillary flows from the watertable start accumulating salts in the root zone and at the soil surface causing reduction in crop yields (Kijne et al., 1998). In situations where the shallow groundwater is of good quality, it is possible to tap and re-use the groundwater recharge by using horizontal tile drains or vertical tube wells (Keller et al. 1996, Khan and Rushton 1997, Rushton 1999, Seckler 1996) or by adopting appropriate cropping and tree plantations. The waterlogging and salinisation situation is complex if low quality water exists in the superficial aquifers consisting of slowly permeable materials such as medium and heavy clays. In these aquifers shallow groundwater pumping is possible only in limited locations and re-use or disposal of saline groundwater poses a major problem. These are typical conditions that exist in the Murray Darling Basin irrigation areas in Australia.

Methodology

Innovative hydrologic research in partnership with growers and irrigation companies has shaped strategic planning and policy development for environmentally sustainable and economically viable management options in major irrigation areas of the Murray-Darling Basin in Australia. Integrated hydrologic, economic, agricultural, and environmental models called SWAGMAN (Salt WAter and Groundwater MANagement) modeling platform, which includes salient features and applications of a detailed process based model (SWAGMAN Destiny), a lumped hydrologic economic model (SWAGMAN Farm) and a distributed biophysical model (SWAGSIM) are used to evaluate the impacts of a range of on-farm interventions on farm income and environmental sustainability. The models are capable of providing a good understanding of the complex interactions between crop, soil, water, salts and shallow watertable dynamics at point, paddock, farm, sub-irrigation, and irrigation area scales. This paper describes applications of a farm scale hydrologic economic framework SWAGMAN Farm to help guide whole farm water balance and net recharge options for environmental management. SWAGMAN Farm is a lumped water and salt balance model which integrates agronomic, climatic, irrigation, hydrogeological, and economic aspects of irrigated agriculture under shallow watertable conditions at a farm scale (Khan et al., 2000). This model has been used to develop management concepts such as “net recharge management for control of shallow watertables” which focuses on managing the component of recharge greater than the vertical and lateral regional groundwater flow. It can simulate the effects of growing a certain crop mix on shallow watertable and soil salinity or it can compute an optimum mix of crops for which the watertable rise and soil salinity remain within the allowable constraints for given hydro-climatic conditions.
Results

A case study using the simulation mode for a hypothetical irrigated farm in the Southern Murray Darling Basin is presented here to show how a dialogue between a farmer and environmental office is started on the basis of existing practices. The total area of the farm is 220 ha with 50 ha of Self Mulching Clays (SMC), 60 ha of Non Self Mulching Clays (NSMC), 80 ha of Red Brown Earths (RBE), 30 ha of sands. The depth to the watertable under the farm is 3.0 m and salinity of the groundwater is 4 dS/m. The total water allocation of the farm is 1400 ML (1 ML=100 mm/ha). The leakage rate under the farm is 0.2 ML/ha per year. The salinity of irrigation water is 0.15 dS/m and salinity of rainfall is 0.01 dS/m. Initial soil water content under the farm is assumed to be 30% (by volume) for all soil types. Average climatic conditions with annual rainfall of 346 mm and 1779 mm of reference evapotranspiration are assumed. The farm annual gross margin is $90,556.

Due to higher gross margins, rice is the most financially attractive land use but its maximum area is restricted due to the constraint on watertable rise. The irrigation application for rice is assumed to be 12 ML/ha, 9 ML/ha for maize, 7 ML/ha for sunflower, 3.5 ML/ha for fababean, 4 ML/ha for canola and 2 ML/ha for barley. The farm rice area in this case is contributing an overall recharge of 37 ML and maize contributes 11 ML/ha whereas irrigated sunflower, canola, barley, and fallow are discharging land uses with individual discharges of 10 ML, 2 ML, 2 ML and 8 ML respectively. The capillary upflow under the farm is zero as the watertable is 3 m deep. The overall rise of watertable is 0.06 m. In this case the farmer is not causing excess recharge but if the farmer increases the area of rice or irrigation levels, corresponding recharge levels are identified and corrective actions such as improved irrigation efficiency or alternative cropping mixes are discussed with the farmer.

The following table shows a summary of the salt balance for the farm. The net increase in salts in the soil above the watertable is 87 tonnes. Recharge under the rice area during the irrigation and fallow periods partly remove (leach) the salt brought in by irrigation and capillary upflow.

<table>
<thead>
<tr>
<th>Salt balance for the example farm (all values in tonnes of salt)</th>
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<tr>
<td>Irrigation Salt</td>
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<td>133</td>
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Conclusions

The results show that policies such as restrictions on area under certain crops, and tradable groundwater recharge/salinity credits both offer higher total gross margin and net present value than the business as usual scenario, specifically in the long run—a win win options for the farmers and the environment. Sensitivity features included in SWAGMAN Farm have helped promote awareness of critical parameters influencing the model results, and have highlighted where effort needs to be expended in determining those parameters that will improve confidence in the model results.

References