SALTMOD: A TOOL FOR THE INTERWEAVING OF IRRIGATION AND DRAINAGE FOR SALINITY CONTROL

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Hitherto, SALTMOD[1] was used to analyse data from pilot areas (Egypt, India, Portugal) where data were available for calibration. For this ILRI symposium it is used to demonstrate the complex inter-actions between irrigation, watertable, salinity and agriculture.

A scenario is presented for an area with a watertable at 10 m depth when irrigation starts. There are two seasons, an irrigation season and a non-irrigation season, when agriculture is rainfed. Initially, during the irrigation season, 100% of the area is irrigated. There is no natural or artificial drainage and no use of groundwater for irrigation.For this scenario, SALTMOD is run in 'automatic gear': the program runs for 15 years without changes in external boundary conditions (e.g. rainfall) but it generates automatic internal responses to changing internal conditions, such as the farmers' responses, which are simulated through in-built mechanisms. For example:

- reduction of irrigated area when irrigation water is scarce,
- reduction in irrigation supply per ha when the watertable becomes shallow,
- abandoning land upon salinization.

In this scenario, the option to change conditions annually and manually ('manual gear') by interactive intervention is not used.

Figure 1 shows that the irrigated area decreases in the first 4 years from 100% to about 80% and in the years 8 to 12 it again decreases to less then 70%. These reductions have different causes.

Figure 1 also shows the reason for the first reduction. It presents the irrigation sufficiency, defined here as the ratio between actual evapotranspiration (ETa) and the potential evapotranspiration (ETp) of the irrigated crops. In the first 4 years, the sufficiency increases from less than 70% to over 80%. Apparently there is not enough irrigation water available to irrigate all crops to full sufficiency and the farmers leave some of the land fallow so that more water can be applied to the remaining irrigated land. The fallow land is not permanent but in crop rotation. Figure 1 shows that the sufficiency increases sharply during the years 4 to 6. To understand the reason of this increase, we look at the behaviour of the watertable.

Figure 2 shows that the depth of the watertable decreases steadily during the first four years, i.e. the watertable is rising. Especially during the fourth year there is a sharp rise, due to a smaller porosity of the soil. From the fifth year onwards, the depth of the watertable becomes less than 1 m, and deep percolation losses can no longer occur. As a result, the irrigation sufficiency increases to almost 100%.

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[1] SALTMOD is an agro-hydro-salinity model developed by Ir. Oosterbaan.

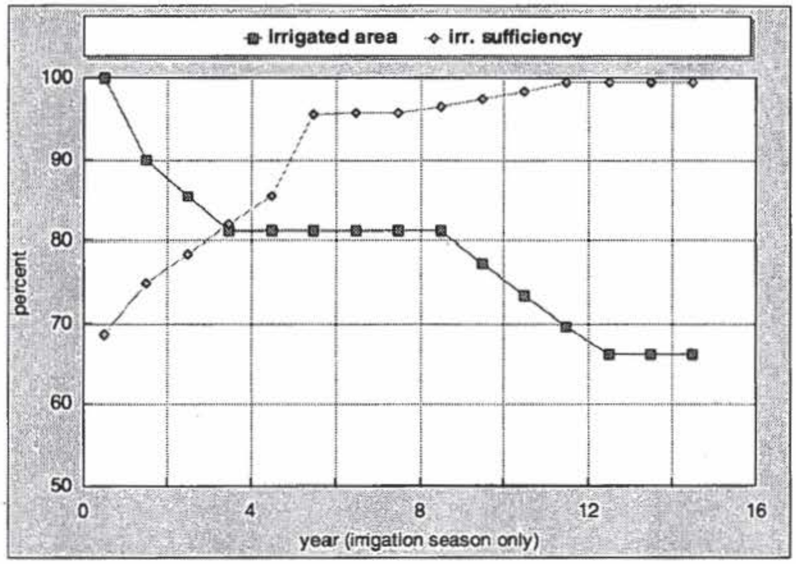

Figure 1. Effects of size of irrigated area on irrigation sufficiency

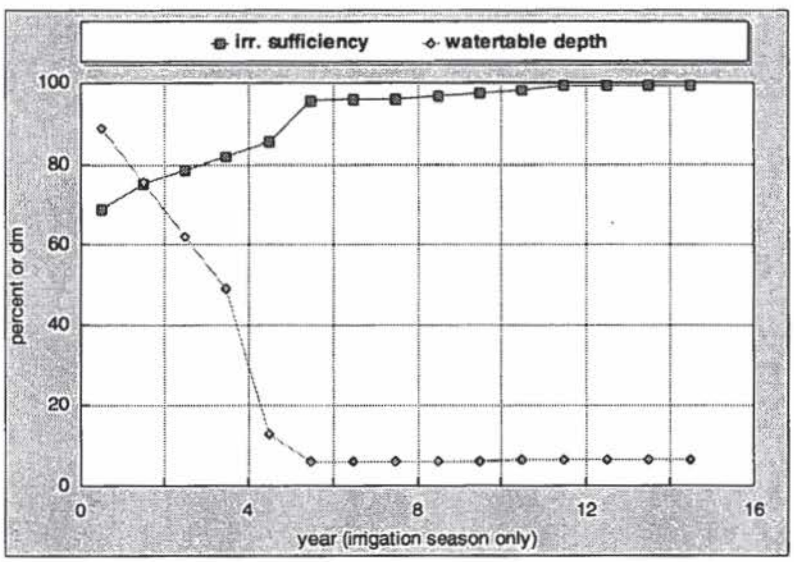

Figure 2. Effects of watertable depth on irrigation sufficiency

The irrigation effectiveness is not only determined by sufficiency but also by efficiency. This is defined here as the ratio between the amount of irrigation water used by the crop (ETi) and the amount of irrigation water applied (Irr). Figure 3 shows that the irrigation efficiency decreases slightly during the first 4 years as the irrigated area decreases and more water can be applied to the irrigated land, so that also the irrigation losses increase. In the years 4 to 6 the efficiency increases sharply from less than 70 to about 80%, although the irrigation application remains stable. After year 8, the irrigation application increases again while the efficiency goes down. An explanation of both features is partly offered in Figure 5 and more fully in the later figures.

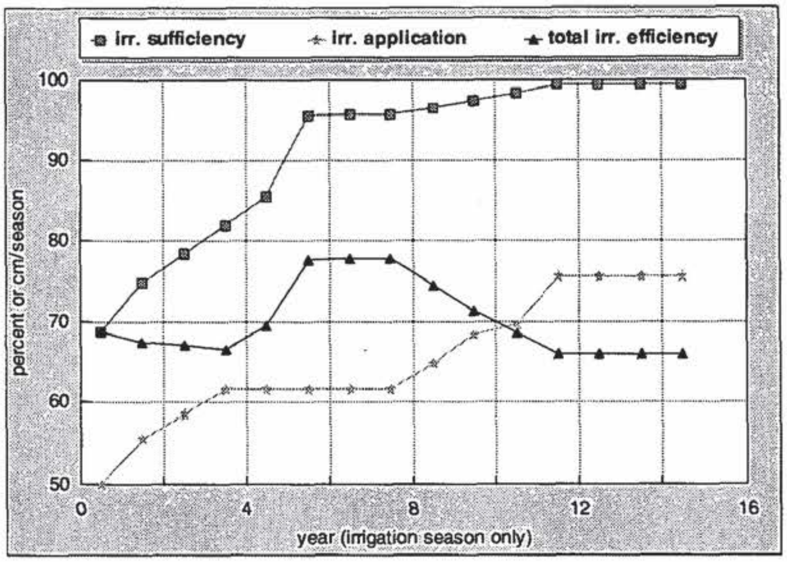

Figure 3. Changes in irrigation sufficiency, irrigation application and total irrigation efficiency

Figure 4 shows that the soil salinity hardly increases during the first four years, as it is checked by the reduction of the irrigated area, higher irrigation applications and more leaching of salts. Hence, the initially low irrigation sufficiency was not the only reason for fallowing the land. Salinity control is a second reason. When, towards year 6, the watertable comes close to the soil surface, deep percolation losses of irrigation water are restricted. Hence the increase in irrigation efficiency. Due to the reduction in percolation, salt leaching is less and the input of salts by the irrigation water begins to build up the soil salinity. The salinity reaches a maximum in year 9. Thereafter, it decreases again while simultaneously the irrigation application goes up and the efficiency down. Figure 5, which shows the non-irrigated area, may shed some light on this phenomenon.

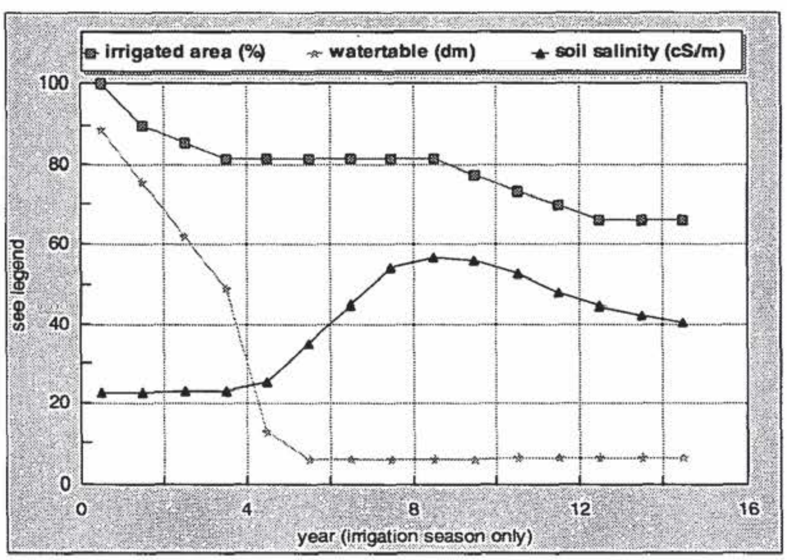

Figure 4. Interrelations between irrigated area, watertable depth and soil salinity

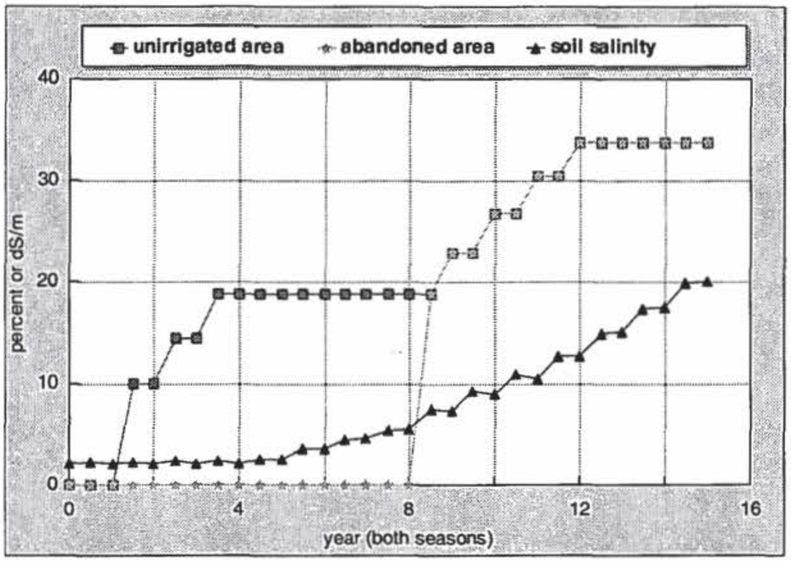

Figure 5. Changes in size of unirrigated area, abandoned area and soil salinity

The unirrigated (rotational fallow) area in Figure 5 increases from 0 to about 20% in the first four years. After this, the area remains constant until year 8. Thereafter, the fallow land increases again to more than 30%. This land becomes permanently fallow because it is abandoned. Its soil salinity reaches high values (20 dS/m). The abandoned area has a dry topsoil and groundwater is evaporated through capillary rise from the watertable. The area serves as a natural 'drain'. The salts brought in by the irrigation water accumulate here. The abandoned land permits drainage of the irrigated land. This explains why, in Figure 2, the irrigation application is increased after year 8, while the efficiency diminishes, and with it, the salinity (see Figure 4).

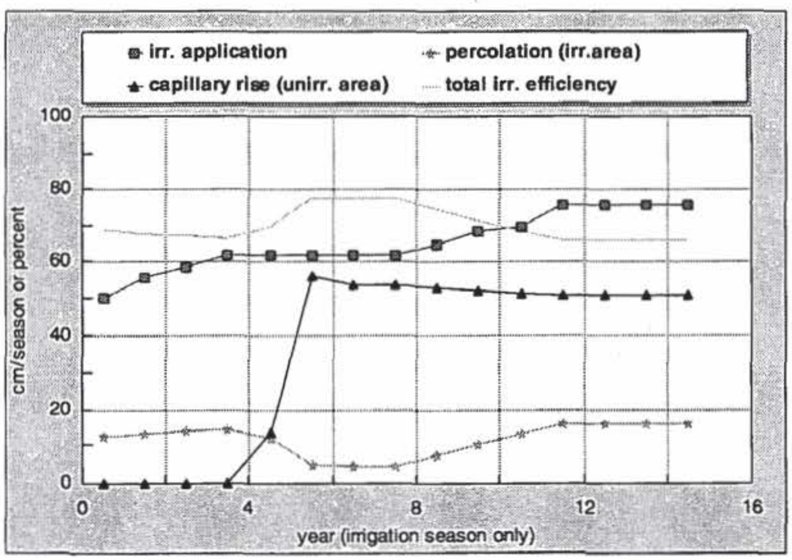

Figure 6. Changes in irrigation application, capillary rise, percolation and total irrigation efficiency

A summary of the variation of some hydrologic factors in time is given in Figure 6, showing stabilization at the end.

Conclusions

1. Irrigation and agricultural practices both determine the water and salt balance, which in turn determine these practices. There is a boomerang effect. All contributing factors are interwoven into a coherently knitted tissue.

2. Isolated drainage measures to combat problems of waterlogging and salinity run the risk of failure.

3. Hydro-agro-salinity models such as SALTMOD are a useful tool to understand the the intricate interrelations.

ILRI is developing a model that combines the SALTMOD program in different polygons with the SGMP[2] model for the flow of groundwater between the polygons: a Regional Salinity Model (RSM).

Discussion

The author explained that the graphs shown during the presentation (and reproduced in this paper (ed.)) were produced with a commercially available spreadsheet program, on the basis of output data from SALTMOD. The model produces a number of standard graphics, but they are not ideal for presentation. Results from the model were checked with field results, e.g. in Egypt, India, Pakistan and Portugal. Asked about farmers responses the author answered that SALTMOD can give three farmers responses. In practice when the watertable below a field rises, the farmer will reduce the irrigation application on that field. When the soil in a field becomes too saline, the farmer will abandon that field and concentrate available water on other fields. When water is scarce and the farmer does not have enough water available to irrigate all his fields, he will introduce fallow periods. If a user of SALTMOD selects the option *farmers response*, then the model (1) reduces applications on fields where the watertable rises too high, (2) abandons salinized fields and (3) introduces fallow periods when water is scarce. In answer to the last question, the author explained that SALTMOD was also applied on pilot areas in Mexico.

[2] SGMP is a numerical groundwater model developed by ILRI. It is discussed further in Dr. Boonstra's contribution to these proceedings.