International Journal of Computer and Information Technology (ISSN: 2279 – 0764)
Volume 03 – Issue 04, July 2014

Modelisation by SALTMOD of Leaching Fraction and Crops Rotation as Relevant Tools for Salinity Management in the Irrigated area of Dyiar Al-Hujjej,Tunisia

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Abstract---- **Irrigated agriculture faces serious problems of soil salinization in the arid and semi-arid regions of the world. Tunisian saline soils occupy about 25% of the total irrigated area. In this study, the irrigated area of "Diyar El Hujjaj" in Tunisia was considered when sea water intrusion and a salinisation of the aquifer were observed. As a result, many pumping wells and farms have been abandoned. An expensive surface fresh water transfer from more than 100 Km was done and a mixture between aquifer salty water and surface water is common practice.**

In this paper, SaltMod model was used to simulate and analyze the soil salinity evolution under several water management scenarios. The first one was a new practice (simultaneously growth of strawberry and pepper). The others concerned the soil salinity evolution under crops rotation compounded by irrigated high value crops, fallow and rainfed crops using an alternative water supply options: groundwater, surface water and a mixture of surface water and groundwater.

Results show that in using only groundwater, simulated soil salinity reaches its peak of about 12 dS m^{-1} when average salinity as high as 9 dS m^{-1} was recorded, and then decreases significantly to a level of 2 dS/m when surface water is applied. However these conditions are not usually met in the study area conditions as the crop water requirement is fairly difficult to be satisfied by surface water irrigation.

The new farming practices option using mixture of surface and groundwater could be sufficient to keep soil within an acceptable range of salinity level of about 2.5 dS/m and 5 dS/m during the first and the second year respectively.

Under the case study conditions, using the mixture of groundwater and surface water could be a viable alternative for irrigation with an agriculture practices including crops rotation, fallow and/or rainfed crops.

Thus, to assure the agricultural success in areas at high risk of salinity, it appears indispensable to control the economical factors relating to the interaction between land attribution and irrigated area management and study the feasibility of the water desalination for agriculture particularly for crops of high added value.

Keywords--component; sea water intrusion, salinisation, Mixture water, Leaching fraction, Crops rotation, Saltmod, Tunisia.

I. INTRODUCTION

Tunisia has more than 400,000 hectares of irrigated land, 25% are affected by salinization (Hamrouni and Daghari, 2010). In Tunisia, the main source of salinization of irrigated area is irrigation water, (Slama, 2004). Sodium chloride is the most prevalent salt in Tunisian water resources. In the oases where the average water consumption per hectare is about 20 000 m^3, more than 40 tons of salts are brought annually per hectare but it is a sandy soil where leaching is easy and a significant rate of gypsum is present even if the average rainfall is only about 100 mm.

A study was conducted in Tunisia since the sixties showed that the yield reduction as a function of salinity is significant. It was 50 % and 40 % respectively for tomato and pepper when water irrigation salinity is slightly above 3 g/l. For forage sorghum, watermelons and beans, irrigation water with a salinity of 3 g/l causes a drop in yields of 30% (CRUESI, 1970).

Water tables in Tunisia have varying levels of salt (Tab.1) and a total dissolved salt more than 1.5 g/l is generally encountered. In Tunisia, the percentage of aquifer water with a salinity less than 1.5 g/l doesn't exceed 20% in the case of deep aquifers and 9% in the case of shallow aquifers.

Table 1. Classification of groundwater resources according to their salinity (DGRE, 1980-2005)

Deep aquifers	
Percentage of water resources (%)	Total dissolved salt (g/l)
19,9	Less than 1,5
56,7	1,5 to 3
22,0	3 to 5
1,4	5 to 7,5
Shallow aquifers	
Percentage of water resources(%)	Total dissolved salt(g/l)
8,4	Less than 1,5
31,7	1,5 to 3
39,0	3 to 5
13,7	5 to 7,5
5,0	7,5 to 10
2,2	more than 10

Our study area is the irrigated area of Diyar El Hujjej (latitude: 37° 05′ 15″ N, longitude 11° 02′ 07″ E) located in Korba delegation, about 66 km south-east of the city of Tunis in the Cap Bon peninsula. Rainfall and annual evapotranspiration are respectively 441 mm and 1166 mm. Sea water intrusion and generalized salinisation were observed in this irrigated area. The main water resources in the region are Korba groundwater. The total number of wells has changed from 8008 to 9349 between 1980 and 2005. The number of abandoned wells, due to water sea intrusion, has increased from 1268 in 1980 to 3200 in 2005 (Ben Hammouda, 2008). The salinity aquifer map prepared in 1963 shows the presence of salinities varying between 2.1 g/l and 3.43 g/l. In 2007, the salinity varied between 2.8 and 10.5 g/l with an average of 6.3 g/l. Due to these considerations and in the aim to safeguard this irrigated area, the Tunisian ministry of Agriculture decides to transfer surface water from the north west of Tunisia via the famous Medjerda-Cap Bon Aqueduct (100 Km length).

The surface water volume supplied for irrigation to all the study area is 1,569.467 m^3; 1,714.603 m^3 and 1,714.492 m^3 for the years 2000, 2011 and 2012 respectively. The largest consumption is recorded during the months April, May and June (more than 10^6 m^3) corresponding to the full growth period of tomato and strawberry. Crops water requirements calculated by the CROPWAT model are about 2,545.965 m^3. According to the farmers association, the gap is filled by pumped aquifer salty water to be mixed with the surface water.

II. MATERIALS AND METHODS

Granular analysis was carried out and the percentage of clay, silt and sand were respectively 9.57%, 35.7% and 55.35%. (clay: 9.57%, silt: 35.7% sand: 55.35%). The crust is everywhere at a depth of 20 cm sometimes, which limited the vocation to vegetable crops and forage mainly. Farm size is divided into two classes 0-4 and 4-10 ha respectively, each occupying 435 ha with 185 farmers and 365 ha with 60 farmers.

Several models have been developed during the recent years for the management of salinity (HYDRUS, SWATRE etc...). All these models need a lot of input parameters; their determination is very difficult and needs a lot of time. In our work, we will use the free SaltMod model; it doesn't need a lot of parameters but it can also predict the behavior of farmers in the perception of salinity, (Oosterbaan and al., 2002). When salinity is so high and we must stop irrigation, SaltMod proposes two solutions, a practice of rainfed crops or a simple abound of farms. The outputs of SaltMod are shown under graphics and tables.

In this paper, SaltMod model was used to simulate and analyze four water management scenarios encountered in our area:

- Case of new practice very encountered in our irrigated area: strawberry-pepper cultivated simultaneously in the same plot two successive years, during September-May for the first crop and during May-August for the second. The area occupied by pepper jumps from 55 ha to 100 ha between 2000 and 2010. It's the unique area in Tunisia where strawberry is cultivated and it's about 250 ha.
- The crops rotation used by farmers and recommended by the consulting office (BICHE, 2008) when a mixture water is used, it's the common situation.
- The crops rotation used by farmers and recommended by the consulting office if surface water that come from another geographic area become abundant and salty aquifer water will be not used.
- The crops rotation used by farmers and recommended by the consulting office if only local salty groundwater is used, in the case of lack of surface water transferred from the north west of Tunisia, due to the high energy cost or in the case of conflict between regions. Now, transfer of water between different geographic regions is highly contested in Tunisia.

Salty profiles were measured under vegetables crops (tomato, pepper, strawberry, squash) irrigated by surface water, by aquifer water or by mixture water. Also salinities were measured under rainfed and even under fallow with different irrigated previous crops during 2011. The method of saturated paste and electromagnetic techniques (Géonics EM38) were used, (Ramon, 2011). A comparison between observed and simulated salinities was done.

III. NUMERICAL SIMULATION ANALYSIS

3.1 First scenario: modelization of the succession strawberry-pepper

In the case of salty water, SaltMod can also modelize the recommended leaching fraction. In our case, without leaching, salinity will rise and will jump to 8 dS m^{-1} since the second year and only rainfed crops will be growth but farms area is very small, and such practice is not profitable. All the following simulations will be done with leaching fraction.

Under strawberry-pepper and even if leaching fraction is provided, salinity continues to rise and already the minimum value predicted by SaltMod during the second year was more than 2.5 dS m^{-1} (green curve in figure 1). Under strawberry Tilda, salinity measured in the field during the second year is equal to 3.57 dS m^{-1}.We see that it is impossible to keep the crops strawberry-pepper more than two consecutive years. Farmers plot change every two years and practice rotations. After the strawberry-pepper (end of august), the plot is abandoned under fallow or farmers cultivate faba that can be used as green manure. Measured salinity observed under faba dropped to less than 2.5 dS m^{-1} in March and reached even 1 dS m^{-1} under rainfed wheat and fallow in some farms. When salinization spreads, two possibilities are offered by SaltMod, i) the farmers grow rainfed crops then salinity decreases due to leaching provoked by rain (red curve in figure 1) or ii) no leaching is done, salinity stays very high (gray curve in figure 1)

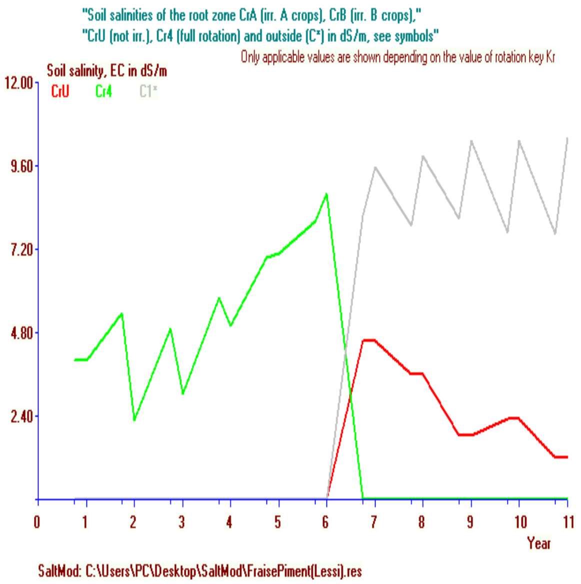

Figure 1: Simulated soil salinity under strawberry-pepper with leaching fraction (green curve) and under rainfed crops with leaching (red curve) and without leaching (gray curve).

3.2 Second scenario: crops rotation with mixture water

A current crops rotation proposed by the consulting office has been modeled: end spring-summer irrigated vegetable (like tomatoes), summer fallow (bare soil), autumn-winter-spring crops (like squash or cabbage). For this crops rotation, salinities remain acceptable during the first year (less than 5 dS m^{-1}). They will increase and reaches about 10 dS m^{-1} at the end of the second year (green curve in figure 2). Farmers do not keep the same succession of crops rotation on the same site more than one year. In fact, the tomato is never grown on the same plot two successive years. Here too, the measurements show that the observed salinity under tomato is 5.6 dS m^{-1}. Under fallow, the salinity remains high during dry summer (about 7 dS m^{-1}) but it reaches 2 dS m^{-1} after the rainy months.

After SaltMod, since the second year, farmers must abandon irrigated crops and use only rainfed crops (red curve in figure 2), then salinity will decrease to 4 dS m^{-1}, 3 dS m^{-1}, 2 dS m^{-1},and 1 dS m^{-1} respectively since the 3th , 5th, 7th and 9th year if leaching is done by rain. The salinity increases during the dry season and decreases during the humid season due to leaching.

In the case of no leaching (gray curve in figure 2), salinity stays very important, about 12 dS m^{-1}.

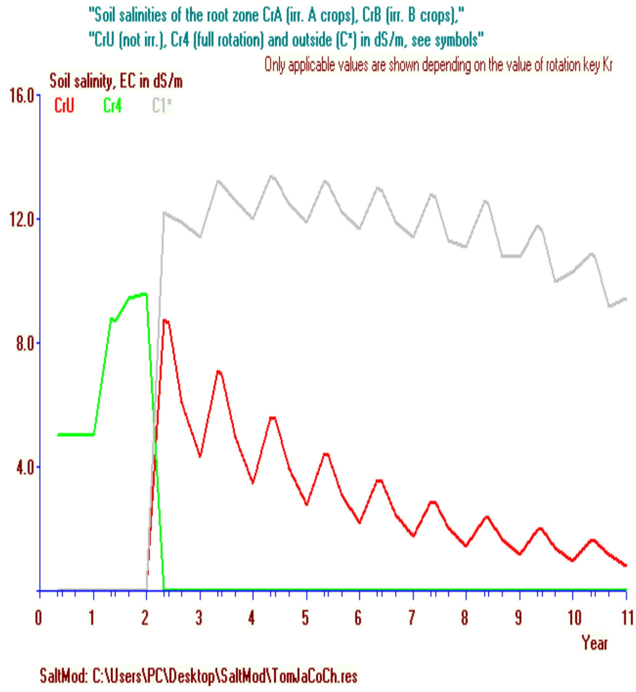

Figure 2: Simulated soil salinity under crops rotation: tomato -fallow-squash-cabbage when surface and aquifer water are mixed (green curve), under rainfed crops with leaching (red curve) and without leaching (gray curve).

3.3 Scenario three: crops rotation and surface water is available enough

We keep the same crops rotation in scenario 2 with opportunities to meet all the crops water requirements from surface water and will not need to use the aquifer salty water. Salinity increases during the dry season (May, August) and decreased during the rainy season (September, April) (Tab. 1). During the first year, salinities will be acceptable but since the second year , salinity will increase and reaches 11.5 dS m^{-1}. Salinities fall thereafter during the rainy season, but they remain high, above 4.35 dS m^{-1}. We understand why farmers change plots, make rotations and practice rainfed crops. We see clearly that even when farmers irrigated with surface water, if they keep the same crops rotation, soil salinization will occur specially during the dry summer. Also, the soil is plowed in the aim to facilitate the infiltration of rain water and leaching.

Table 2: Simulated soil salinity under the same crops rotation if only surface water is used at different dates (dS m^{-1})

Season	First Year	Second Year	Third Year	Fourth Year
End of June	6.43	6.89	6.84	6.79
End of august	6.80	8.53	9.93	11.50
End of January	4.80	5.12	5.50	5.91
End of April	4.35	4.42	4.49	4.51

3.4 Fourth scenario: crops rotation and if only aquifer water is available

We keep the same previous crops rotation but we suppose we have to use only the aquifer salty water; salinity reaches 6 dS m^{-1} during the first year and jumps to more 12 dS m^{-1} at the end of the second year. Under these conditions, we must abandon irrigation and only fallow and rainfed agriculture is possible, that what was generally done before the transfer of surface water. This situation is encountered in practice in the case of farmers using only aquifer water where the measured salinities were always more than 3.71 dS m^{-1} under irrigated tomato. Pepper was abandoned because of unmarketable and low dimension of pods. They didn't grow any irrigated crops during the rest of the year and a leaching of salt occurs during the rainy months. In another farm, salinity reached 6.47 g/l under irrigated tomato while it's less than 1.5 g/l under fallow and rainfed wheat after some rains.

IV. CONCLUSION

SaltMod used to modelize the evolution of salinity for extended periods showed that without leaching fraction and crops rotation, no practice is sustainable. The crops rotation most commonly practiced by farmers, namely summer irrigated crops-type tomato, fallow, autumn or winter or spring irrigated crops is the most viable. In the absence of surface water, salinization will occur and widespread. Adoption of fallow and rainfed crops is a must. Succession strawberry-pepper can't been kept more than two years on the same plot; salinities will increase annually

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