# 2- SALTMED: Calibration and validation using Field data from Egypt and Syria

R. Ragab[1], A. Ghaibeh[2], N. Malash[3], J. Abdel Gawad [2] and A. Arslan [2]

**ABSTRACT**

**A successful water management scheme for irrigated crops requires an integrated approach that accounts for water, crop, soil and field management.**

**Generally the use of saline water for irrigation requires a selection of appropriate salt tolerant crops and an improvement in water management and maintenance of soil physical properties to ensure adequate soil permeability to meet leaching requirements. As such an integrated approach is the way forward to facilitate the use of saline waters for irrigation, to minimize drainage disposal problems and to maximize the beneficial use of multiple water sources. Soil salinization is a long-term process, long duration experiments, as well as robust comprehensive, rather than single-process orientated models are required for long term predictions. Most existing models are designed for a specific irrigation system, specific process such as water and solute movement, infiltration, leaching or water uptake by plant roots or a combination of them. There is a shortage in models of a generic nature, models that can be used for a variety of irrigation systems, soil types, soil stratifications, crops and trees, water application strategies (blending or cyclic), leaching requirements and water qualities. SALTMED model has been developed for such generic applications. The model employs well established water and solute transport, evapotranspiration and crop water uptake equations. Following its development stage, the model has been run with several examples of applications using data from the literature. The model successfully illustrated the effect of the irrigation system, the soil type, irrigation and irrigation salinity level on soil moisture and salinity distribution, leaching requirements, and crop yield in all cases. Subsequently, the model has been calibrated and tested using data of five complete growing seasons from Syria and Egypt. The model successfully predicted the impact of salinity on yield, water uptake, soil moisture and salinity distribution with reasonable degree of accuracy. The model provides the academics with a research tool and field mangers with a powerful tool to manage their water, crop and soil in an effective way to save water and protect the environment. The results shown here are samples of a fairly comprehensive report .**

## II. II SALTMED Model calibration using Field data of Egypt and Syria

The model has been calibrated using the 100% fresh water treatment of 2002 in both Syria and Egypt. The calibration was primarily focused on yield prediction of the 100% fresh irrigation water treatment.

The meteorological data of El- Raheb site in Egypt were obtained from Shebin-Elkoam weather station, 3 km away from the field site. The meteorological data of Syria site in Dair Ezore were measured at the field site. The irrigation files contained field measurements of flow rate, duration of each irrigation and salinity of irrigation water. Plant parameters such as maximum plant height and rooting depth, length of each growth stage, planting date and harvesting date were based on field measurements and

---

[1] Centre for Ecology and Hydrology, CEH-Wallingford, OX10 8BB, UK, E-mail: Rag@ceh.ac.uk
[2] ACSAD, Syria
[3] University of Menofeia, Faculty of Agriculture, Egypt

records. Crop coefficients such as Kc, Kcb, Fc were based on FAO - Irrigation & Drainage paper No.56 which forms part of the SALTMED built-in crop database. π50 and H50 parameters were obtained by calibration.

Soil parameters such as the saturated and unsaturated hydraulic conductivity, were largely based on field measurements while water retention curve (pF curve) was based on laboratory measurements. Initial soil moisture and salinity were based on measurements either in laboratory or in the field. Adjustments on some soil parameters were carried out in order to obtain good calibration. Following the successful calibration, the same set of crop parameters such as Kc, Kcb, Fc, π50, maximum height and maximum rooting depth were used for both Egypt and Syria for all season. The calibrated soil parameters of each site, Egypt and Syria were fixed for all other treatments and for all years. Examples of the calibration and calibration parameters are given in the following section. The crop parameters used for the calibration of 100% fresh water treatment of Egypt can be seen in figure 1, while figure 2 shows the soil physical parameters for Egypt's soil. The initial soil moisture and salinity with depth are shown in figure 3. The red line in Figure 4 is masked by the blue line. Figure 4 shows the calibration against crop yield while figure 5 shows the evolution of crop parameters used in the calibration. Figure 6 illustrates the evapotranspiration and its two components; transpiration and bare soil evaporation over the growing season of 2002.

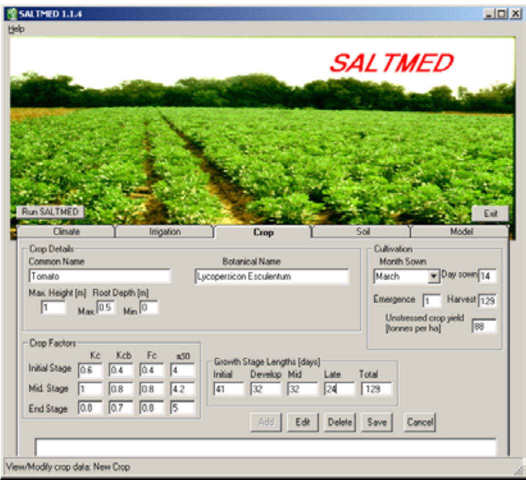



Figure 1. Crop parameters used in the calibration of Egypt 100% fresh water treatment, 2002 season.

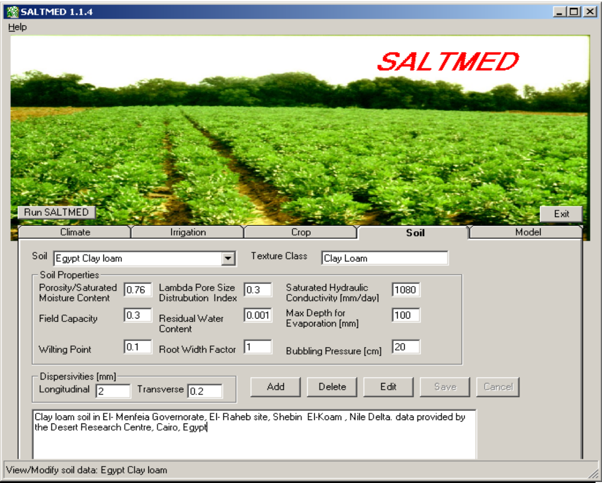



Figure 2. Soil parameters used in the calibration of Egypt 100% fresh water treatment, 2002 season.

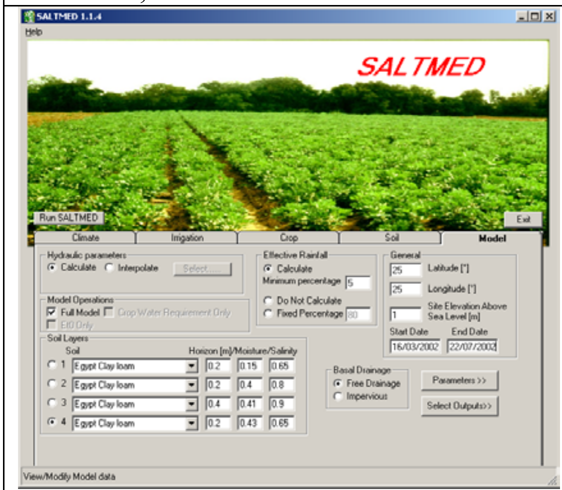



Figure 3. Soil initial conditions used in the calibration of Egypt 100% freshwater treatment, 2002 season.

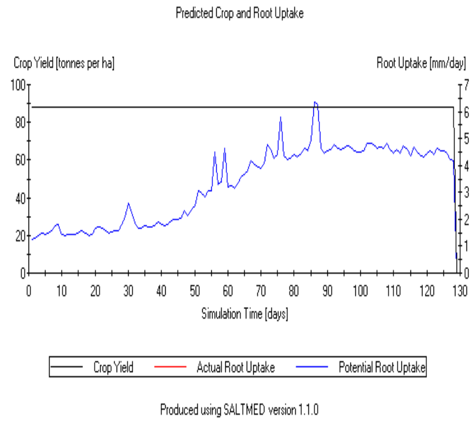



Figure 4. Crop yield as obtained by the calibration of Egypt 100% fresh water treatment, 2002 season.

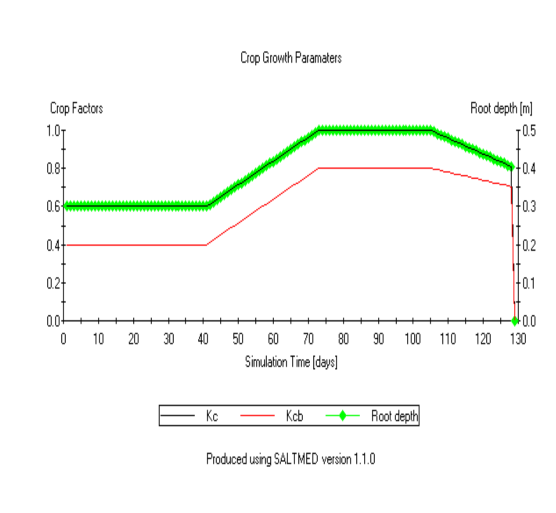



Figure 5. Crop parameters used in the calibration of 100% fresh water treatment 2002 season, Egypt.

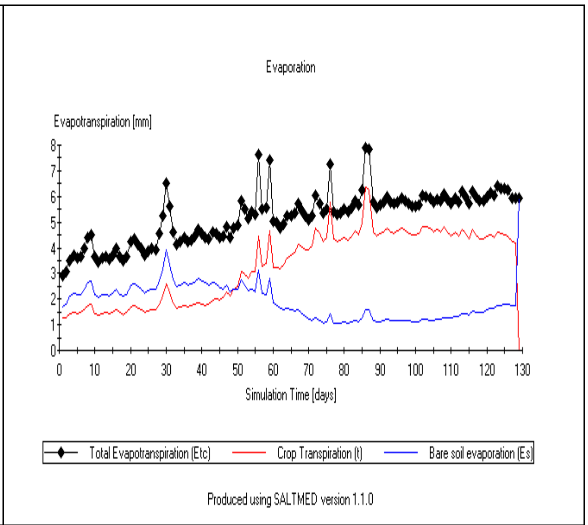



Figure 6. Evapotranspiration, crop transpiration and bare soil evaporation obtained by the calibration of 100% fresh water treatment, 2002 season, Egypt.

## II. II. II Calibration with Syria field data of 2002

The calibration was carried out against the yield of the 100% fresh water treatment of 2002. Apart from the length of growth stages, sowing and harvests dates, which differ between Egypt and Syria, the crop parameters obtained from the successful calibration were the same as those of Egypt as shown in figures 7, 8, 9 and 10.

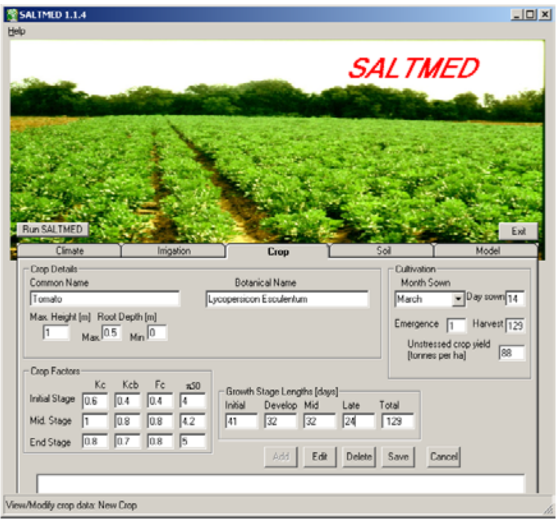




Figure 7. Crop parameters used in the calibration of Syria 100% fresh water treatment, 2002 season.

Figure 8. Soil parameters used in the calibration of Syria 100% fresh water treatment, 2002 season.

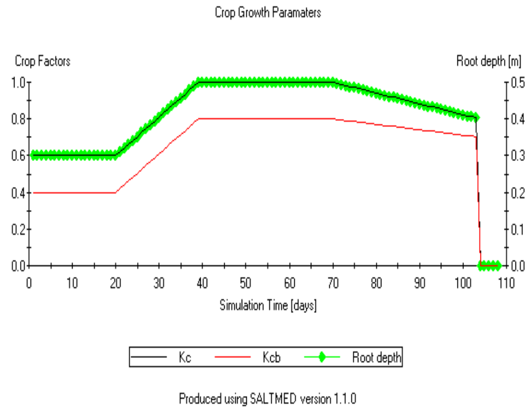



Figure 9. Crop parameters used in the calibration of 100% fresh water treatment, 2002 season, Syria.

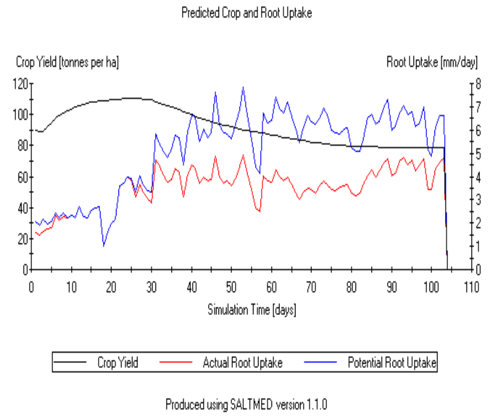



Figure 10. Evapotranspiration, crop transpiration and bare soil evaporation obtained by the calibration of 100% fresh water treatment, 2002 season, Syria

## II. III. SALTMED Validation against field observations

Following the successful calibration of the 100%fresh water irrigation treatment of year 2002, the model was run with the same calibration parameters for the rest of the irrigation treatments of 2002 and all treatments of years 2000 and 2001 in Egypt and Syria. The model was tested against yield, water uptake, soil moisture and soil salinity distribution.

## II. III. I. EGYPT - Yield

Simulated and observed yields of 2000, 2001 and 2002 under furrow irrigation were compared as illustrated in figure 11, 12 and 13 respectively. Generally, there is good agreement between simulated and observed yield of the three years. The alternative irrigation treatments produced slightly less yield than the mixed water treatment. As expected, decreasing the ratio of fresh water or increasing the ratio of saline water led to a decrease in the yield. Figure 14, shows the 1:1 relation between simulated and observed yield under furrow for all years and all treatments. The points are reasonably close to the 1:1 line indicating a good agreement between model predictions and observed yield. Figures 15, 16 and 17 show the simulated and observed yield under drip irrigation for years 2000, 2001, and 2002 respectively while figure 18 shows the 1:1 relation between simulated and observed yield for all treatments and all years under drip irrigation. The figures indicate a good agreement between simulated and observed yield. It also shows a higher yield under drip irrigation than under furrow. Furthermore, the points in figure 18 are closer to the 1:1 line when compared to figure 14 indicating relatively a better agreement under drip irrigation than under furrow. As under furrow, the yield also decreased with increasing the salinity level of irrigation water and the yield under alternative treatment was slightly less than the mixed treatment. Figure 19 shows a summary of Egypt results for both furrow and drip irrigation for all irrigation treatments and years. The 1:1 relation indicates that the predicted yields under both irrigation systems and all treatment for the three years were reasonably close to the observed ones. Table 1shows the observed and simulated yield under furrow mixed irrigation treatment while table 2 shows the % difference between simulated and observed yield calculated as a difference between simulated and observed divided by the observed yield. The average difference of the 16 trials was around 10%. However, a negative difference of up to 21% was noticed under 60 and 40% fresh water irrigation treatment indicating the underestimation of the yield by the model. This could be attributed to the nutrient load in the drainage water. The latter has been added to the fresh water before irrigation in the mixed water treatments. This relatively high nutrient load is mainly due to the excessive irrigation and fertilizers application in the surrounding fields from which the drainage water was generated. The high level of nitrogen in water of moderate salinity level could have contributed to the unexpected and unusual increase in the observed yield. This could explain how 60% fresh water mixed with 40% drainage water produced more yield than 100% fresh water in the 2000 season.

The effect of nutrients load on yield goes beyond the SALTMED capability. Future development of SALTMED model should take the impact of nutrient on yield into account. Table 3 shows the high level of nitrogen in drainage water compared with fresh water. Table 4 shows the simulated and observed yield under drip – mixed irrigation water treatment. The average difference of the 16 trials was 2.77% as given in table 5. As in furrow mixed treatments, a similar trend was found under drip mixed treatments, the maximum negative difference of 10 and 11% were noticed in the mixed treatments of 60 and 40% fresh water. This once again could be attributed to the presence of high nutrients level in the drainage water that has been mixed with the fresh water for irrigation. Table 6 shows the simulated and observed yield under furrow alternative irrigation water treatments while table 7 gives the % difference between simulated and observed yield. The average difference here is 3.24 %. The maximum negative differences here were 7.8, 8.5 and 11% associated with the 60 and 40% fresh and 100% saline water treatments respectively, possibly due to the same reason as in mixed treatments.

Table 8 gives the simulated and observed yield under drip alternative treatments while table 9 shows the % difference between simulated and observed yield. The average difference here is 1.79% with a maximum difference of 8.6% under 100% saline water (drainage water). The positive difference in cases of 100% saline waters as in tables 5, and 9 means the simulated yield is higher than the observed and that could be attributed to other reasons other than the nutrients load in the drainage water. These could include the balance accuracy. Usually scales used in the field are relatively less sensitive / crude and might produce up to 5% error. Other reasons could include, high local osmotic potentials due to salt accumulation in a certain part of the root zone caused by uneven distribution of irrigation water, drying leaves due to severe weather conditions, pests, and other factors operating in the field that have negative impacts on yield. The overall average difference between simulated and observed yield for Egypt drip and furrow for the three years and for the 64 field trials was -3.65%. These by and large are very good results.

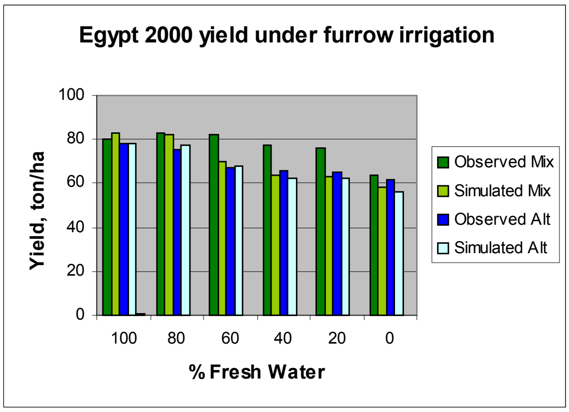



Figure 11. Simulated and observed yield under different furrow irrigation treatments in Egypt, 2000.

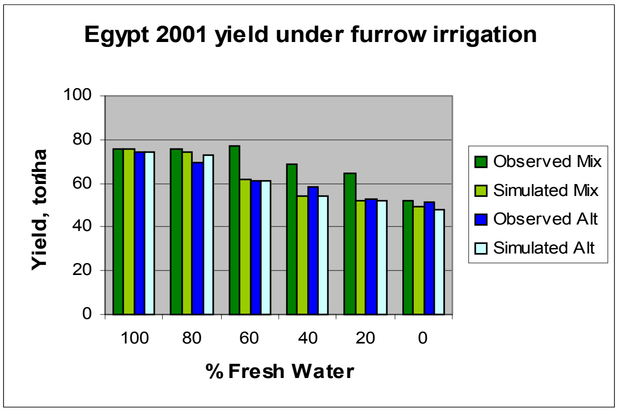



Figure 12. Simulated and observed yield under different furrow irrigation treatments in Egypt, 2001.

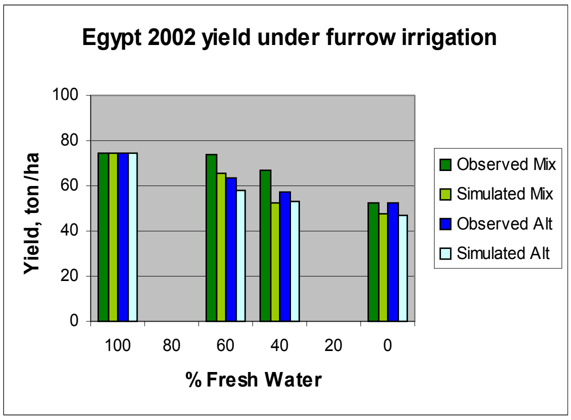



Figure 13. Simulated and observed yield under different furrow irrigation treatments in Egypt, 2002.

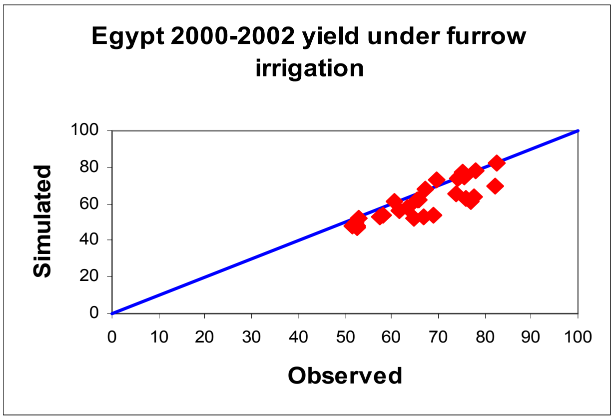



Figure 14. Comparison between all simulated and observed yield under furrow irrigation, 2000-2002.

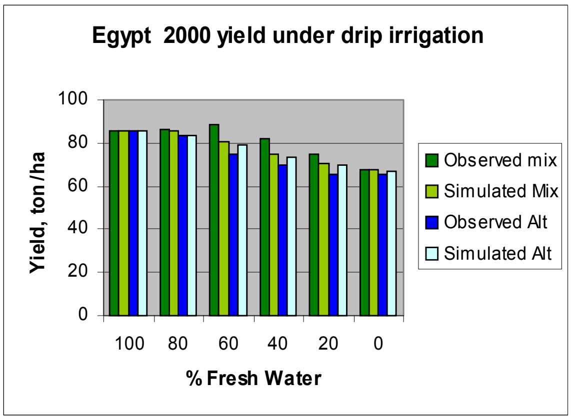



Figure 15. Simulated and observed yield under different drip irrigation treatments in Egypt, 2000.

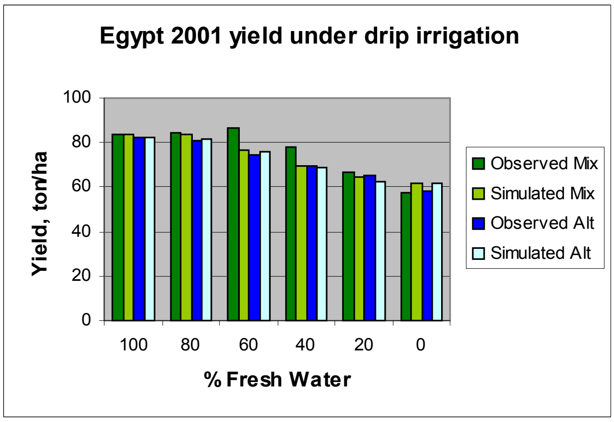
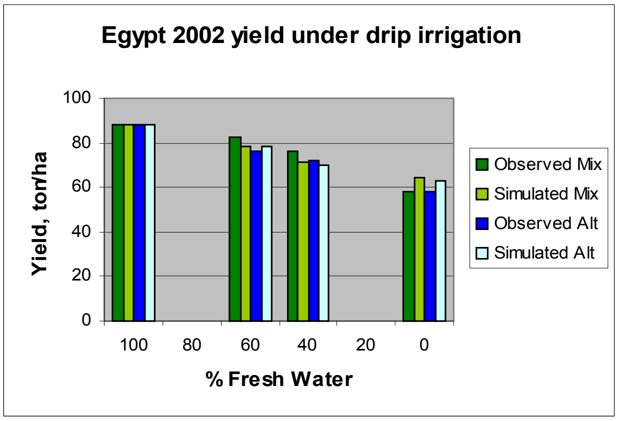
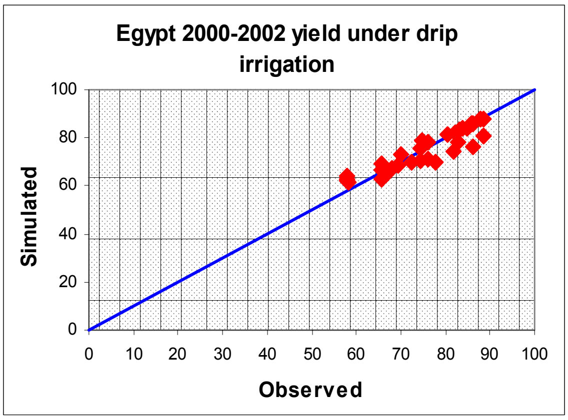



Figure 16. Simulated and observed yield under different irrigation treatments in Egypt, 2001.




| Figure 17. Simulated and observed yield under different drip irrigation treatments in Egypt, 2002. | Figure 18. Comparison between all simulated and observed yield under drip irrigation, 2000-2002. |
|---|---|

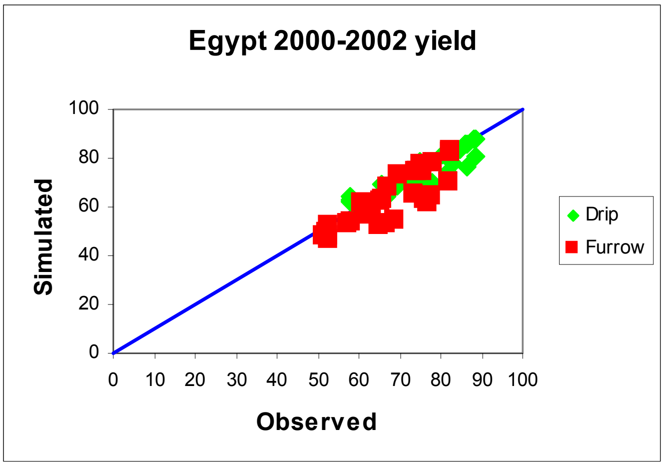



Figure 19. Comparison between all simulated and observed yield under furrow and drip irrigation, 2000-2002.

Table 1. Simulated and observed yield in Egypt under furrow irrigation-mixed treatment.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Fresh water | 2000 | | 2001 | | 2002 | |
| | Yield (ton/ha) | | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated | Observed | Simulated |
| 100 | 80.0 | 82.7 | 75.7 | 75.7 | 74.5 | 74.5 |
| 80 | 82.7 | 82.5 | 75.6 | 74.6 | n.d. | |
| 60 | 82.2 | 69.8 | 76.9 | 61.5 | 73.7 | 65.3 |
| 40 | 77.7 | 64.0 | 69.0 | 54.2 | 67.0 | 52.6 |
| 20 | 76.0 | 62.7 | 64.9 | 52.1 | n.d. | |
| 0 | 63.4 | 58.2 | 52.2 | 49.3 | 52.6 | 47.6 |

Table 2. % difference between observed and simulated yield in Egypt under furrow irrigation-mixed treatment

| Fresh Water | % Error | | |
|---|---|---|---|
| % | 2000 | 2001 | 2002 |
| 100 | 0.00 | 0.00 | 0.00 |
| 80 | -0.24 | -1.32 | n.d. |
| 60 | -15.09 | -20.03 | -11.40 |
| 40 | -17.63 | -21.45 | -21.49 |
| 20 | -17.50 | -19.72 | n.d. |
| 0 | -8.20 | -5.56 | -9.51 |

Average difference = -10.36%

Table 3. Nutrient analysis of fresh water and drainage water

| Element / Water source | N ppm | P ppm | K ppm | Fe ppm | Zn ppm | Mn ppm |
|---|---|---|---|---|---|---|
| Irrigation water (fresh) | 3.2 | 0.214 | 7.25 | 0.12 | 0.17 | 0.03 |
| Drainage water | 25.8 | 0.381 | 10.93 | 0.23 | 1.20 | 0.30 |

Table 4. Simulated and observed yield in Egypt under drip irrigation-mixed treatment.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Fresh | 2000 | | 2001 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated | Observed | Simulated |
| 100 | 85.8 | 85.8 | 83.7 | 83.7 | 88.0 | 88.0 |
| 80 | 86.2 | 85.8 | 84.7 | 83.7 | n.d. | |
| 60 | 88.7 | 80.9 | 86.3 | 76.5 | 82.8 | 78.2 |
| 40 | 81.7 | 74.5 | 77.8 | 69.7 | 76.2 | 71.2 |
| 20 | 74.5 | 70.6 | 66.7 | 64.6 | n.d. | |
| 0 | 67.9 | 67.5 | 57.8 | 61.9 | 57.9 | 64.1 |

Table 5. % difference between observed and simulated yield in Egypt under drip irrigation-mixed treatment

| Fresh Water | % Error | | |
|---|---|---|---|
| % | 2000 | 2001 | 2002 |
| 100 | 0.00 | 0.00 | 0.00 |
| 80 | -0.46 | -1.18 | n.d. |
| 60 | -8.79 | -11.36 | -5.56 |
| 40 | -8.81 | -10.41 | -6.56 |
| 20 | -5.23 | -3.15 | n.d. |
| 0 | -0.59 | 7.09 | 10.71 |

Average difference = -2.77

Table 6. Simulated and observed yield in Egypt under furrow irrigation-alternative treatment.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| resh | 2000 | | 2001 | | 2002 | |
| /ater | Yield (ton/ha) | | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated | Observed | Simulated |
| 100 | 78.2 | 78.2 | 74.1 | 74.1 | 74.5 | 74.5 |
| 80 | 75.3 | 77.3 | 69.7 | 72.7 | n.d. | |
| 60 | 67.1 | 68.1 | 60.8 | 61.4 | 63.4 | 58 |
| 40 | 66.0 | 62.6 | 58.3 | 53.9 | 57.4 | 52.9 |
| 20 | 65.4 | 62.3 | 52.8 | 52.3 | n.d. | |
| 0 | 61.5 | 56.5 | 51.5 | 47.8 | 52.6 | 46.7 |

Table 7. % difference between observed and simulated yield in Egypt under furrow irrigation-alternative treatment

| Fresh Water | % Error | | |
|---|---|---|---|
| % | 2000 | 2001 | 2002 |
| 100 | 0.00 | 0.00 | 0.00 |
| 80 | 2.66 | 4.30 | n.d. |
| 60 | 1.49 | 0.99 | -8.52 |
| 40 | -5.15 | -7.55 | -7.84 |
| 20 | -4.74 | -0.95 | n.d. |
| 0 | -8.13 | -7.18 | -11.22 |

Average difference = -3.24

Table 8. Simulated and observed yield in Egypt under drip irrigation-alternative treatment.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Fresh | 2000 | | 2001 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated | Observed | Simulated |
| 100 | 85.8 | 85.8 | 82.3 | 82.3 | 88.0 | 88.0 |
| 80 | 83.3 | 83.6 | 80.6 | 81.6 | n.d. | |
| 60 | 74.9 | 78.9 | 74.5 | 75.6 | 76.2 | 78.3 |
| 40 | 70.0 | 73.2 | 69.4 | 68.6 | 72.3 | 69.6 |
| 20 | 65.5 | 69.5 | 65.5 | 62.6 | n.d. | |
| 0 | 65.8 | 66.6 | 58.1 | 61.7 | 57.9 | 62.9 |

Table 9. % difference between observed and simulated yield in Egypt under drip irrigation-alternative treatment

| Fresh Water | % Error | | |
|---|---|---|---|
| % | 2000 | 2001 | 2002 |
| 100 | 0.00 | 0.00 | 0.00 |
| 80 | 0.36 | 1.24 | n.d. |
| 60 | 5.34 | 1.48 | 2.76 |
| 40 | 4.57 | -1.15 | -3.73 |
| 20 | 6.11 | -4.43 | n.d. |
| 0 | 1.22 | 6.20 | 8.64 |

Average difference = 1.79

## II. III. II. Syria – Yield

The yield was simulated only for the years of 2000 and 2002 as the 2001 yield was severely affected by the nematodes. Figures 20 and 21 show the simulated and observed yields under furrow irrigation for the years of 200 and 2002 respectively. The results are very good and better than those of Egypt as indicated by 1:1 relation in figure 22. Similar results were obtained for drip irrigation as shown in figures 23 and 24 for years of 2000 and 2002 respectively and on the 1:1 relation in figure 25. The overall comparison for Syria for all trials of drip and furrow and for the two years is shown in figure 26. The 1:1 relation looks very good in comparison with Egypt results. This is possibly due to a relatively smaller load of nutrients in the drainage water that has been mixed with the irrigation water in Syria. Table 18 shows the fresh and drainage water analysis. The soluble N in the drainage water is 5.79 mg/l compared with 25.8 in the drainage water of Egypt (Table3). The simulated and observed yields under drip alternative treatments are shown in table 10 while table 11 shows the % difference between simulated and observed yield. The average difference was less than 1% while the maximum difference was around 10% associated with the 100% saline water application. Table 12 show the simulated and observed yields under drip mixed treatment while table 13 shows the % difference between simulated and observed yield. The average difference here was around 2% with a maximum difference of also 10% associated with 100% saline water application as in drip-alternative treatments.

The simulated and observed yields under furrow irrigation alternative treatments are given in table 14 while the % difference is shown in table 15. The average difference here was less than 1% with a maximum difference of around 4% associated with 100% saline water application as in the case of drip irrigation. Similar results under furrow mixed water treatments are shown in tables 16 and 17. The average difference was less than 1% and maximum difference of 4% was also associated with the 100% saline water applications as it was the case with all other treatments. It is worth mentioning that, the model underestimated the yield under the drip 100% saline water by about 10% and slightly overestimated the yield by 4% under furrow for the same treatments. Despite the nitrogen load in drainage water in Syria is relatively smaller than that of Egypt, it could also have contributed to the unexpected high yield. The crop basically has received a total of 5.79 mg/l N of drainage water (no dilution with fresh water) in the 100% saline water applications (table 18). All in all, these are excellent results with overall average difference of around 1%.

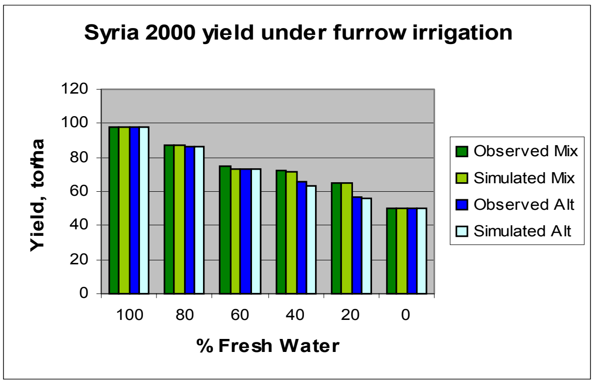



Figure 20. Simulated and observed yield under different furrow irrigation treatments in Syria, 2000.

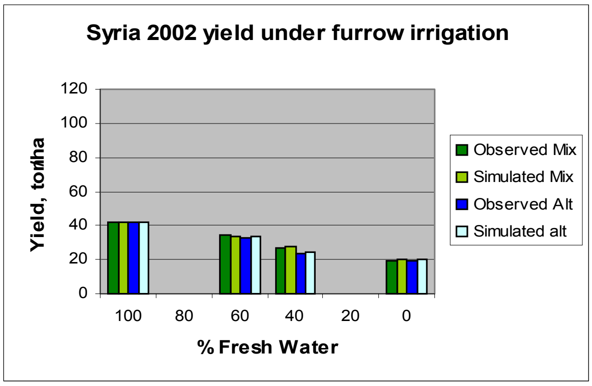



Figure 21. Simulated and observed yield under different furrow irrigation treatments in Syria, 2002.

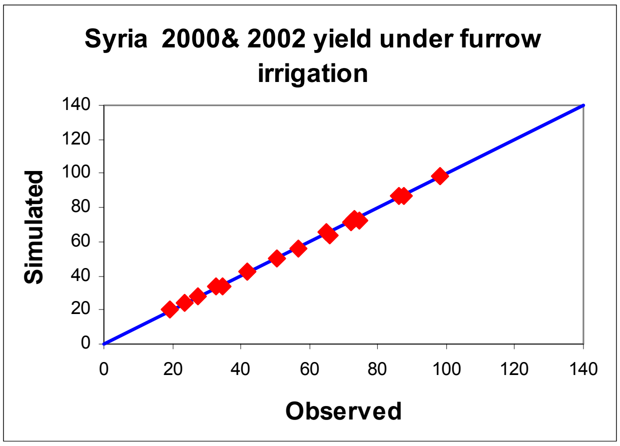
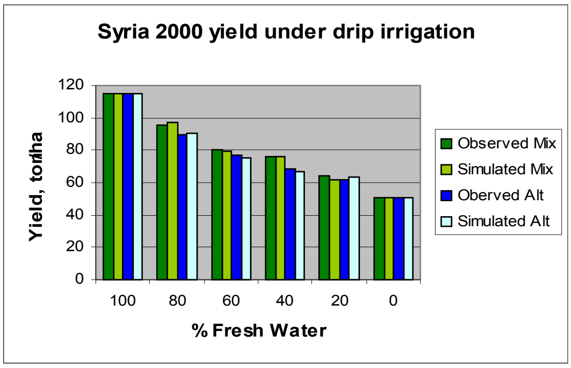
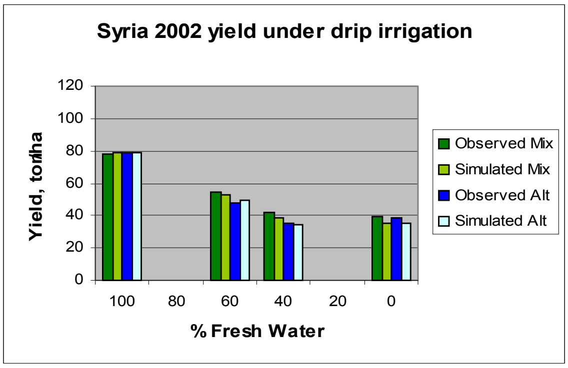
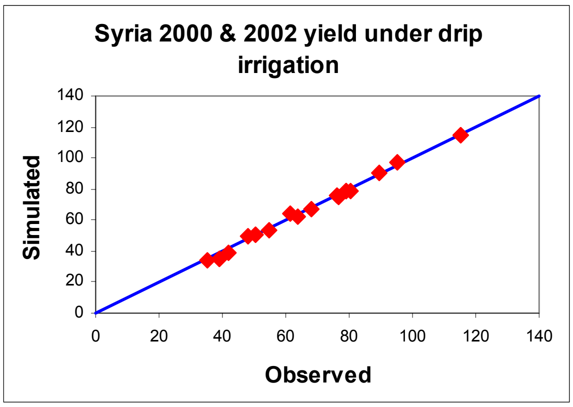


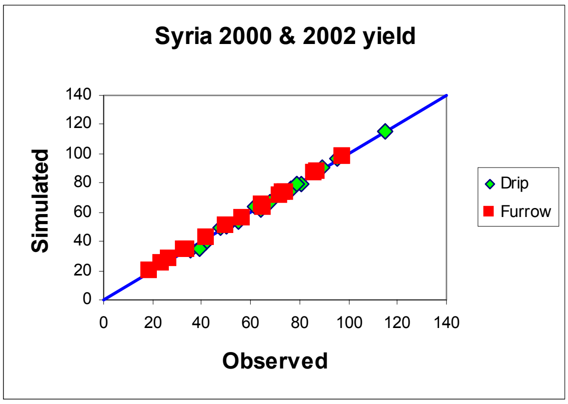

Figure 22. Simulated and observed yield under all furrow irrigation treatments in Syria, 2000-2002.




| Figure 23. Simulated and observed yield under different drip irrigation treatments in Syria, 2000. | Figure 24. Simulated and observed yield under different drip irrigation treatments in Syria, 2002. |
|---|---|




| Figure 25. Simulated and observed yield under all drip irrigation treatments in Syria, 2000-2002. | Figure 26. Simulated and observed yield under all drip and furrow irrigation treatments in Syria, 2000-2002. |
|---|---|

Table 10. Simulated and observed yield in Syria under drip irrigation-alternative treatment.

| | Year | | | |
|---|---|---|---|---|
| Fresh | 2000 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated |
| 100 | 115.0 | 115.0 | 79.0 | 79.0 |
| 80 | 89.5 | 90.8 | n.d. | |
| 60 | 76.5 | 75.3 | 47.9 | 49.2 |
| 40 | 68.1 | 66.7 | 35.4 | 34.2 |
| 20 | 61.6 | 63.8 | n.d. | |
| 0 | 50.3 | 50.6 | 39.0 | 35.0 |

Table 11. % difference between observed and simulated yield in Syria under drip irrigation-alternative treatment

| Fresh Water | % Error | |
|---|---|---|
| % | 2000 | 2002 |
| 100 | 0.00 | 0.00 |
| 80 | 1.45 | n.d. |
| 60 | -1.57 | 2.71 |
| 40 | -2.06 | -3.39 |
| 20 | 3.57 | n.d. |
| 0 | 0.60 | -10.26 |

Average difference = -0.89

Table 12. Simulated and observed yield in Syria under drip irrigation-mixed treatment.

| | Year | | | |
|---|---|---|---|---|
| Fresh | 2000 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated |
| 100 | 115.0 | 115.0 | 77.9 | 79.0 |
| 80 | 95.3 | 96.9 | n.d. | |
| 60 | 80.4 | 79.2 | 54.8 | 53.1 |
| 40 | 76.2 | 75.8 | 41.8 | 38.9 |
| 20 | 63.9 | 62.1 | n.d. | |
| 0 | 50.3 | 50.6 | 39.1 | 35.0 |

Table 13. % difference between observed and simulated yield in Syria under dripirrigation-mixed treatment

| Fresh Water | % Error | |
|---|---|---|
| % | 2000 | 2002 |
| 100 | 0.00 | 0.00 |
| 80 | 1.68 | n.d. |
| 60 | -1.49 | -3.10 |
| 40 | -0.52 | -6.94 |
| 20 | -2.82 | n.d. |
| 0 | 0.60 | -10.49 |

Average difference = -2.17

Table 14. Simulated and observed yield in Syria under furrow irrigation-alternative treatment.

| | Year | | | |
|---|---|---|---|---|
| Fresh | 2000 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated |
| 100 | 98.0 | 98.0 | 42.0 | 42.0 |
| 80 | 86.3 | 86.7 | n.d. | |
| 60 | 73.1 | 73.1 | 32.8 | 33.6 |
| 40 | 65.7 | 63.3 | 23.6 | 24.3 |
| 20 | 56.7 | 55.8 | n.d. | |
| 0 | 50.4 | 50.3 | 19.2 | 20.0 |

Table 15. % difference between observed and simulated yield in Syria under furrow irrigation-alternative treatment

| Fresh Water | % Error | |
|---|---|---|
| % | 2000 | 2002 |
| 100 | 0.00 | 0.00 |
| 80 | 0.46 | n.d. |
| 60 | 0.00 | 2.44 |
| 40 | -3.65 | 2.97 |
| 20 | -1.59 | n.d. |
| 0 | -0.20 | 4.17 |

Average difference = 0.46

Table 16. Simulated and observed yield in Syria under furrow irrigation-mixed treatment.

| | Year | | | |
|---|---|---|---|---|
| Fresh | 2000 | | 2002 | |
| Water | Yield (ton/ha) | | Yield (ton/ha) | |
| % | Observed | Simulated | Observed | Simulated |
| 100 | 98.0 | 98.0 | 42.0 | 42.0 |
| 80 | 87.4 | 87.0 | n.d. | |
| 60 | 74.5 | 72.8 | 34.4 | 33.9 |
| 40 | 72.2 | 71.1 | 27.2 | 27.8 |
| 20 | 65.1 | 65.2 | n.d. | |
| 0 | 50.4 | 50.3 | 19.2 | 20.0 |

Table 17. % difference between observed and simulated yield in Syria under furrow irrigation-alternative treatment

| Fresh Water | % Error | |
|---|---|---|
| % | 2000 | 2002 |
| 100 | 0.00 | 0.00 |
| 80 | -0.46 | n.d. |
| 60 | -2.28 | -1.45 |
| 40 | -1.52 | 2.21 |
| 20 | 0.15 | n.d. |
| 0 | -0.20 | 4.17 |

Average difference = 0.06

Table 18. Syria Fresh and drainage water analysis.

| | pH | EC | Meq/L | | | | | | | | ppm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | dS/m | Ca | Mg | Na | K | Cl | $CO_3$ | $HCO_3$ | SO4 | B | $NO_3$ | $NH_4$ |
| Fresh | 7.50 | 0.80 | 4.16 | 4.05 | 1.9 | 0.05 | 2.09 | 0.0 | 1.9 | 6.17 | 1.29 | 2.6 | Trace |
| drainage | 8.12 | 8.50 | 7.45 | 18.0 | 58.7 | 0.13 | 26.2 | 0.14 | 2.56 | 56.29 | 7.92 | 25.65 | trace |

## III. I. I. Root water uptake/ actual transpiration

The water uptake under field conditions in Egypt and Syria was determined from soil moisture depletion of the root zone and the fraction of the canopy cover over the soil. The soil moisture depletion was calculated as a difference between successive soil moisture profiles (before and after irrigation from soil surface to the bottom of the root zone). The fraction cover of each growth stage was based on FAO – Irrigation and Drainage paper No.56.

Figure 26 shows the simulated and observed water uptake under drip irrigation on 18/6/2002 in Syria while figure 27 shows the simulated and observed water uptake under drip irrigation on 24-25/6/2002 in Egypt. The figures show the decrease in water uptake with the increase of salinity of irrigation water. The simulated and observed values are in good agreement.

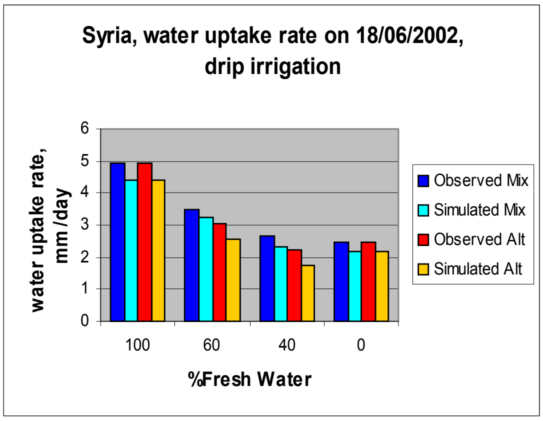



Figure 26. Daily water uptake rate under drip irrigation on 18/06/2002, Syria.

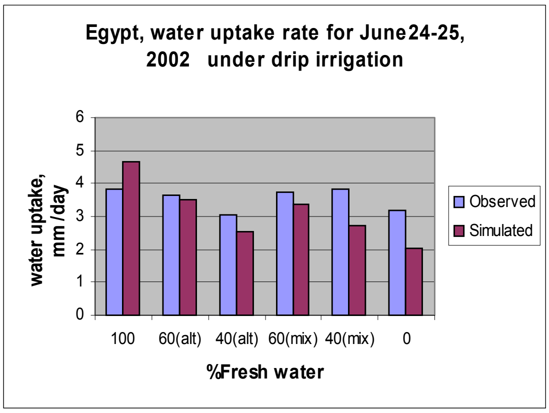



Figure 27 . Water uptake under drip irrigation during June 24-25, 2002, Egypt.

## III. I. II Crop water uptake - yield - irrigation water salinity relationship

The relation between yield, water uptake and salinity of irrigation water for data gathered from Egypt and Syria showed a strong relationship between the yield and the water uptake and salinity of irrigation water. Use of relative yield (see example in Table 19) improved the fit ($R^2$ values). The advantage of using relative (otherwise termed scaled) yield, is the elimination of the effect of other factors such as irrigation systems. The scaled yield and water uptake- water salinity relation (Figures 28, 29, 30 & 31) was best described by a polynomial function of the 4$^{th}$ order.

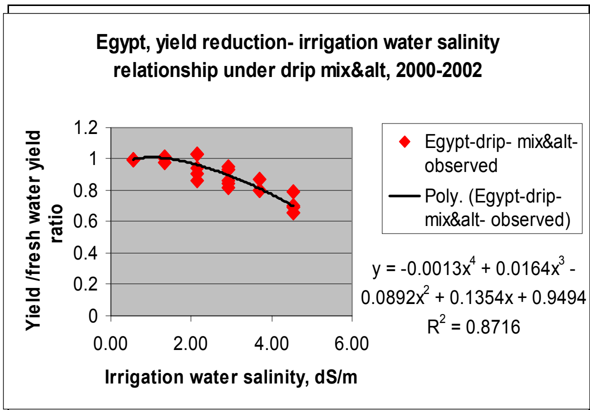



Figure 28. Observed ratio of yield/fresh water yield versus water salinity under drip irrigation, Egypt, 2000-2002

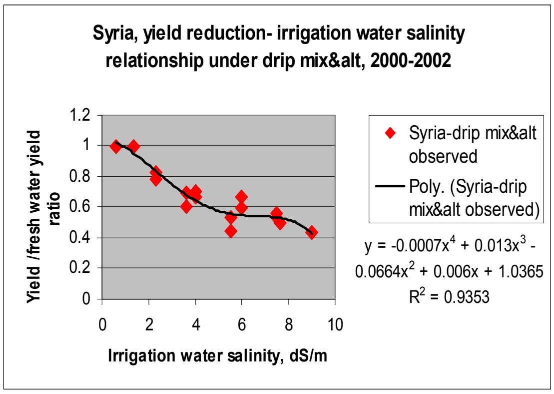



Figure 29.Observed ratio of yield/fresh water yield versus water salinity under drip mix & alt irrigation, Syria, 2000-2002

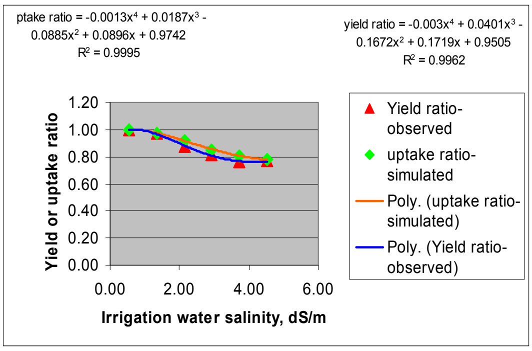



Figure 30. Egypt, observed yield ratio and simulated water uptake ratio versus water salinity under drip irrigation alternative treatment, 2000

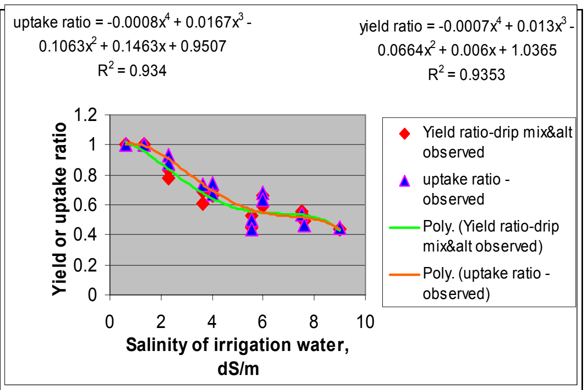



Figure 31. Syria, observed yield and water uptake ratios versus water salinity under drip mixed and alternative treatments, 2000-2002

Table 19. Relative yield and relative water uptake (uptake/uptake under 100% fresh water) under drip alternative treatment for Egypt 2000.

| Egypt drip Alt | | | | | |
|---|---|---|---|---|---|
| Irrigation water | | 2000 | | 2000 | |
| | Salinity | Yield / fresh water yield | | water uptake/fresh water uptake | |
| Fresh | EC dS/m | Observed | Simulated | simulated | observed |
| Water, % | | | | | |
| 100 | 0.55 | 1.00 | 1.00 | 1.00 | 1.00 |
| 80 | 1.35 | 0.97 | 0.97 | 0.97 | 0.90 |
| 60 | 2.15 | 0.87 | 0.92 | 0.92 | 0.71 |
| 40 | 2.93 | 0.82 | 0.85 | 0.85 | 0.68 |
| 20 | 3.71 | 0.76 | 0.81 | 0.81 | 0.69 |
| 0 | 4.53 | 0.77 | 0.78 | 0.78 | 0.65 |

# IV. Soil salinity and soil moisture distribution

The soil moisture and salinity in Egypt and Syria were measured by a variety of methods. Figures 32, 33, 34 & 35 show the simulated and observed soil moisture and salinity profiles. The results iullustrate a good agreement between the observed and simulated values.

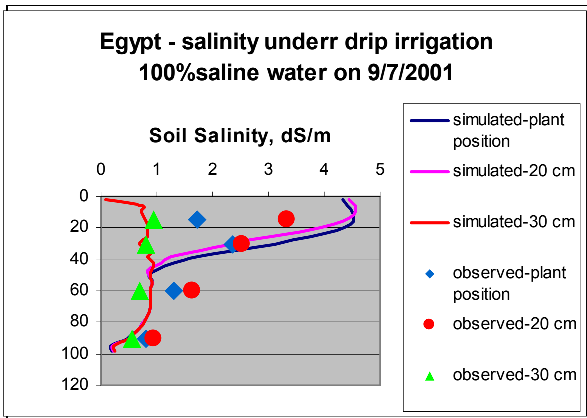



Figure 32. Salinity profiles under drip irrigation 100% saline water on 9/7/2001

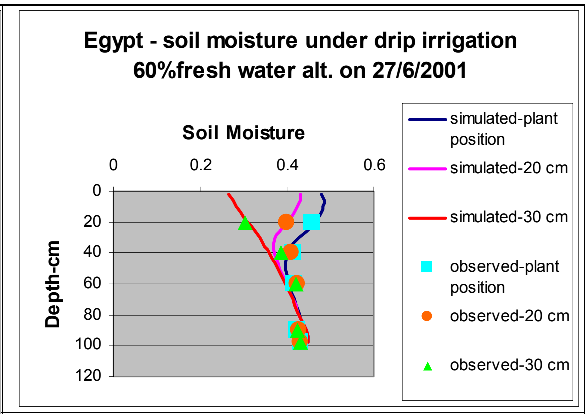



Figure 33. Soil moisture profiles under drip irrigation 60% fresh water alternative treatment on 27/6/2001

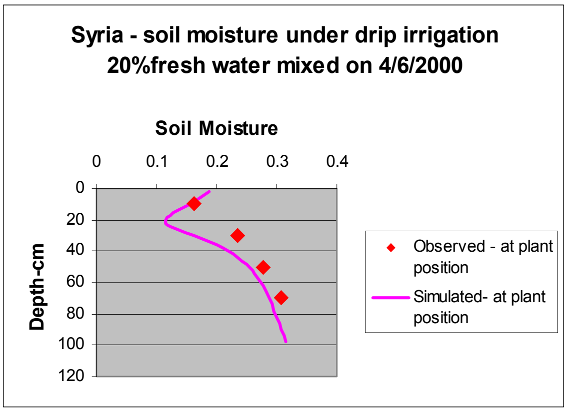



Figure 34. Soil moisture under drip
ation 20% fresh water mixed on 4/6/2000

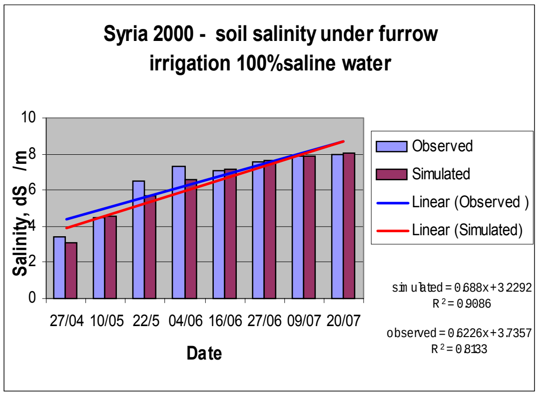



Figure 35. Simulated and observed soil salinity measured by sensors at 25 cm depth under furrow irrigation 100%saline water.

# V. Conclusions

SALTMED model has been developed as a tool to help in the management of water, crop and soil under field conditions. The model was developed to be generic, easy and friendly to use. The model is PC based and can run under windows 95, 98 2000 and windows xp operation systems. It is physically based model and has 3 built-in data bases for soils, crops and irrigation systems. It can run for any irrigation system, any soil type, any water quality and any crop. It accounts for soil heterogeneity. It calculates evapotranspiration, bare soil evaporation, plant water uptake, leaching requirements, soil salinity profiles, soil moisture profiles and yield. During its development stage, the model has been tested against data from literature. The model underwent several stages of debugging and upgrading before it was put for test against the field data of Egypt and Syria. At the first stage the model was calibrated using the 2002 yield data from Egypt and Syria. Following the successful calibration, the same soil and crop parameters were used for testing the model against other treatments of

2002 and all of 2001 and 2000 data. The model proved its ability to handle several hydrodynamic processes acting at the same time in nature. The model was able to successfully simulate yield, water uptake, soil moisture and salinity profiles.

The model highlighted the need for a good quality data to accurately predict soil moisture and salinity profiles. It also indicated during the calibration that the model is sensitive to soil hydraulic parameters and the initial soil moisture and salinity values. This becomes only important if the season is short to the extent that the initial storage of moisture and salinity level plays a significant role. The results obtained from the observation and simulated data indicate that the Floradade variety of tomatoes is salt tolerant and suitable to grow in the Mediterranean region. A water of salinity level of 7 ds/m can only reduce the yield to 50%.

The results indicated that, the relation between both yield and water uptake as function of irrigation water salinity is non linear and better described by polynomial function of $4^{th}$ order. The scaled yield and water uptake by simply dividing the given values by the equivalent values obtained under 100% fresh water would eliminate the effect of external factors and produce more consistent and reliable results.

The scaled water uptake can almost be described by the same equation derived for yield. As such, one can use the scaled water uptake function to predict the yield under a given salinity level of the irrigation water. The water uptake can be estimated from soil moisture profiles using different techniques. These range from accurate measurements at narrow spacing using Time Domain Reflectometry ( TDR ) to less accurate measurements using Neutron Probe or any other intermediate techniques. Similar relations between yield or water uptake and water salinity can also be obtained using soil salinity but that is difficult (not impossible) as soil salinity is very dynamic and changes rapidly over time and space according to irrigation timing, crop growth stage, and leaching management. However, a relation between soil salinity and water salinity can be established. The results obtained could be used at management level to estimate the relative yield under a given irrigation system and water of a given salinity level. To obtain the absolute yield, one can simply multiply the relative yield by the maximum yield obtainable under 100% fresh water.

Good estimation of soil moisture has practical implications. This means that the model is able to estimate the amount of irrigation water required to bring the soil moisture profile from a given soil moisture to a desired soil moisture (usually soil moisture at field capacity). The other implication is, if the soil moisture contents are estimated correctly, it is very likely to lead also to an accurate estimate of salinity and ions distributions. The practical aspect of this conclusion is, if irrigation and fertilizers are applied simultaneously (known as fertigation), one can ensure that the nutrients will be applied in efficient way to the root zone and avoid any losses. The second important aspect is, good prediction of salinity could help avoid salinity build up in the root zone and soil profile and would help in determining the leaching requirements. All these are the ingredients of a good field management.

## IV. Guidelines and Recommendations for farmers and Extension services

1. Floradade tomato variety over yielded all other varieties under saline and non saline condition. Moreover, sugar content in Floradade tomato variety fruits increased with increasing the salinity of irrigation. Growing hybrid tomato varieties such as Floradade will:
   - Produce higher yield under non-saline and saline conditions compared with local varieties.
   - Give higher yield per unit water applied (higher water use efficiency). The water use efficiency of tomato (Floradade variety) for drip irrigation is almost times that of furrow irrigation. Hence we recommend drip irrigation for arid and semi arid conditions using different water qualities.
2. Irrigating tomato using drip irrigation system produced higher yield compared with the traditional surface irrigation method.
3. Irrigating tomato using drip irrigation system reduces water consumption compared with the traditional surface irrigation method.
4. Producing seedlings in greenhouse and transferring them to the field under Syrian climatic conditions
   - Reduces frost injury of the seedlings at early spring. Survival of tomato seedlings after transplanting in the field was higher than 80% during the course of 4 years study even for the water quality treatment of 8 dS/m
   - Increases the growing and production period.
   - Reduces water consumption.
   - Increases tomato yield.
   - Gives more time for land preparation and the previous crop growth.
5. Saline irrigation water having an EC of 8 dS/m can produce about 50% of the yield of that grown under non saline condition, when an additional leaching fraction of 15% is applied with the irrigation water.
6. Higher sugar and total dissolved solids in tomato fruits can be obtained using moderately and saline irrigation water.
7. Using saline irrigation water for tomato growing saves fresh water to irrigate more lands and more crops.
8. Using saline drainage water for tomato growing reduces the agriculture drainage volume and solve the problem of disposal of saline drainage water.
9. Increasing irrigation frequency reduces salts accumulation in soil and increases the yield.
10. Using drainage water of about 2 dS/m does not cause any reduction in growth and yield of tomato plants or even has an enhancement effect if drainage water contained nutrients from leached fertilizers of other neighbouring fields.
11. Using drip irrigation system reduces the salinity hazards when compared with furrow irrigation as the drip irrigation is applied more frequently and keeps the soil moisture high enough to counter balance the negative impact of salinity
12. Pre-treatments of young seedlings with drought, salinity or PEG may increase salt tolerance of tomato plants in later stages
13. There is no significant difference found between alternative and mixed treatment in terms of yield. However, mixing management is recommended if both fresh water and saline water are always available otherwise use alternative treatment, irrigate with saline water when fresh water is not available particularly at later stages. Alternative treatment would save more fresh water that could be used to grow more crops.
14. Models are useful tool for management and assessments. Soil salinization is a long process and models are useful tool to predict salinization and possible yield under combination of field, crop and soil and water salinity conditions.