A new version of the agro-hydro-soil-salinity model SaltMod allowing for annually varied seasonal inputs of hydrological conditions.

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Abstract

The much used agro-hydro-soil-salinity model SaltMod has been extended to include the possibility to create tables for annually varying inputs of seasonal hydrological conditions like quantity of irrigation water and rainfall. Previously the model could be made to temporarily stop after each year of calculations to offer the possibility to change seasonal input data if required. Now all these changes can be entered into input tables so that the model can complete its run without interruption using the annually varying seasonal data as defined in the input tables.

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1. Introduction

The standard agro-hydro-soil-salinity model SaltMod, which is freely available, has been widely used, especially drainage and soil salinity calculations in irrigated lands in (semi) arid regions **[Ref. 1].**

If so desired the program can be instructed to temporarily halt the calculations after each year the program has been told to run, so that the user can enter changes in the input data like for example rainfall, which can be very variable from year to year. Similarly the cropping pattern can be varied each year if opportune (*Fig. 1*).

The download of the SaltMod manual with an overview of equations used for water and salt balances is specified in **[Ref. 2].** A summary of the equations is shown in the **Appendix.**
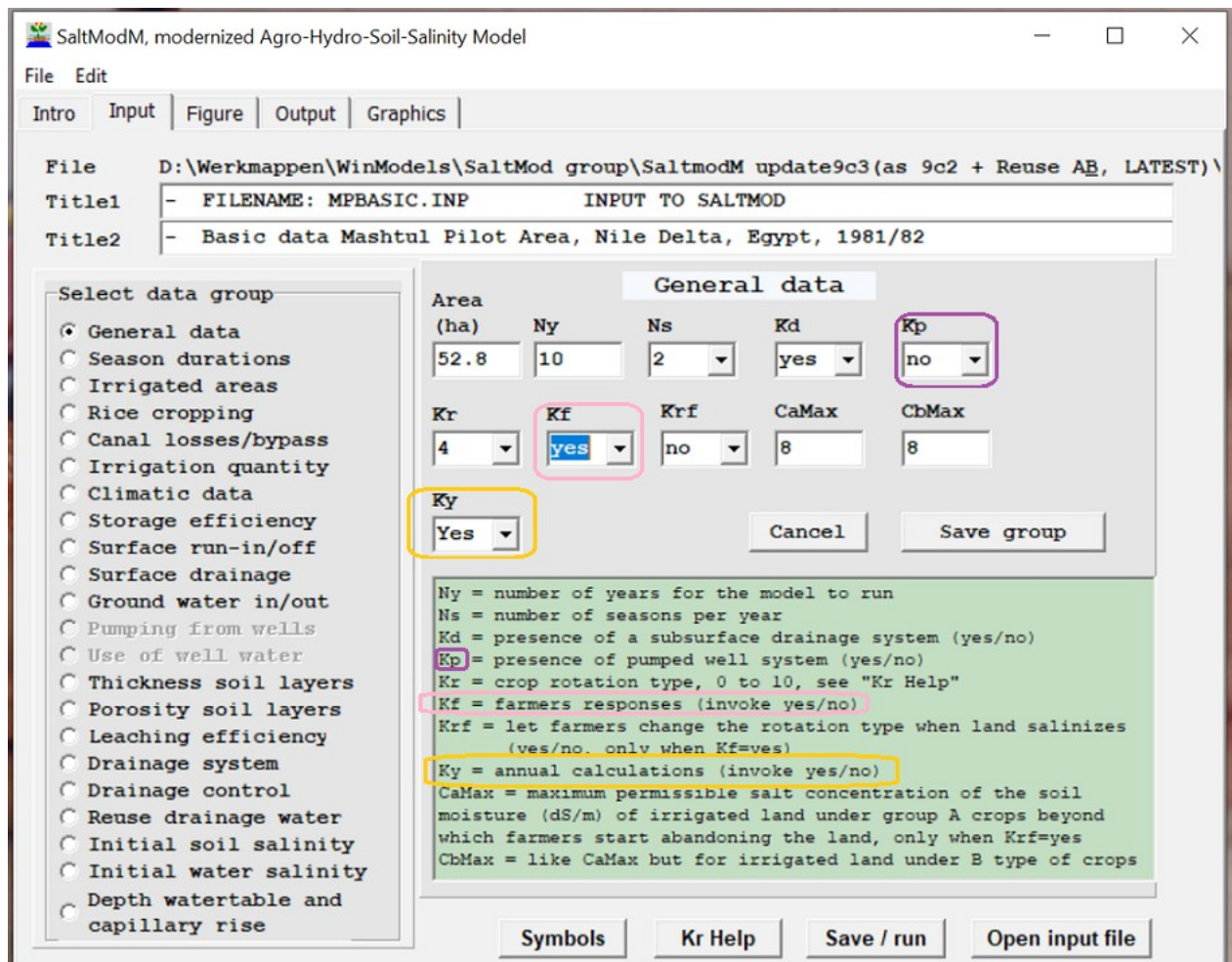
Figure 1. *Selection of annual calculations in SaltMod (yellow markers) and farmers' responses (pink markers).This example stems from the modernized SaltMod program: SatModM **[Ref. 3]**.*
There is no pumping from wells as the index Kp (purple marker) is set to "no", but there is a subsurface drainage system as the Kd index is set to "yes".

2. Descriptions

Instead of using the Ky index "yes" as in figure 1, the SaltModMY model **[Ref. 4]** uses an "Annual Inputs" sheet to enter the annually seasonal hydrological inputs, so that the program does not need to halt every year to change these inputs after each year of calculation (*Fig. 2*).
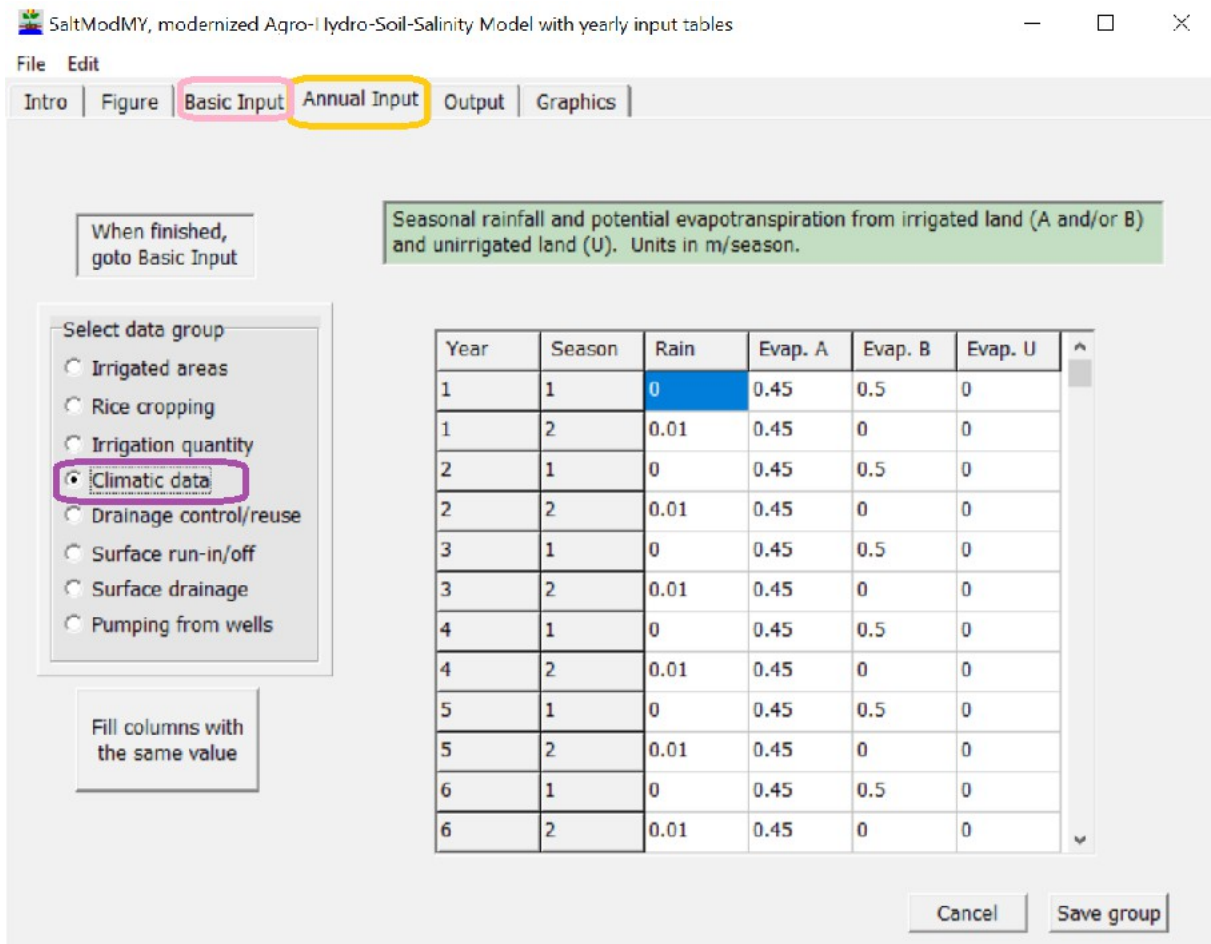
Figure 2. Showing the Annual Input sheet (yellow marker) of the SaltModMY program with an example of the Climatic data (purple marker). As there is no unirrigated land over all the years and all the seasons, the potential evaporation from fallow land (Evap. U) has been set to zero all over. In this example there are two seasons per year, though the model accepts a maximum of four seasons per year.
The Basic Input (rose marker) can be seen clicking on the corresponding sheet header (pink marker).
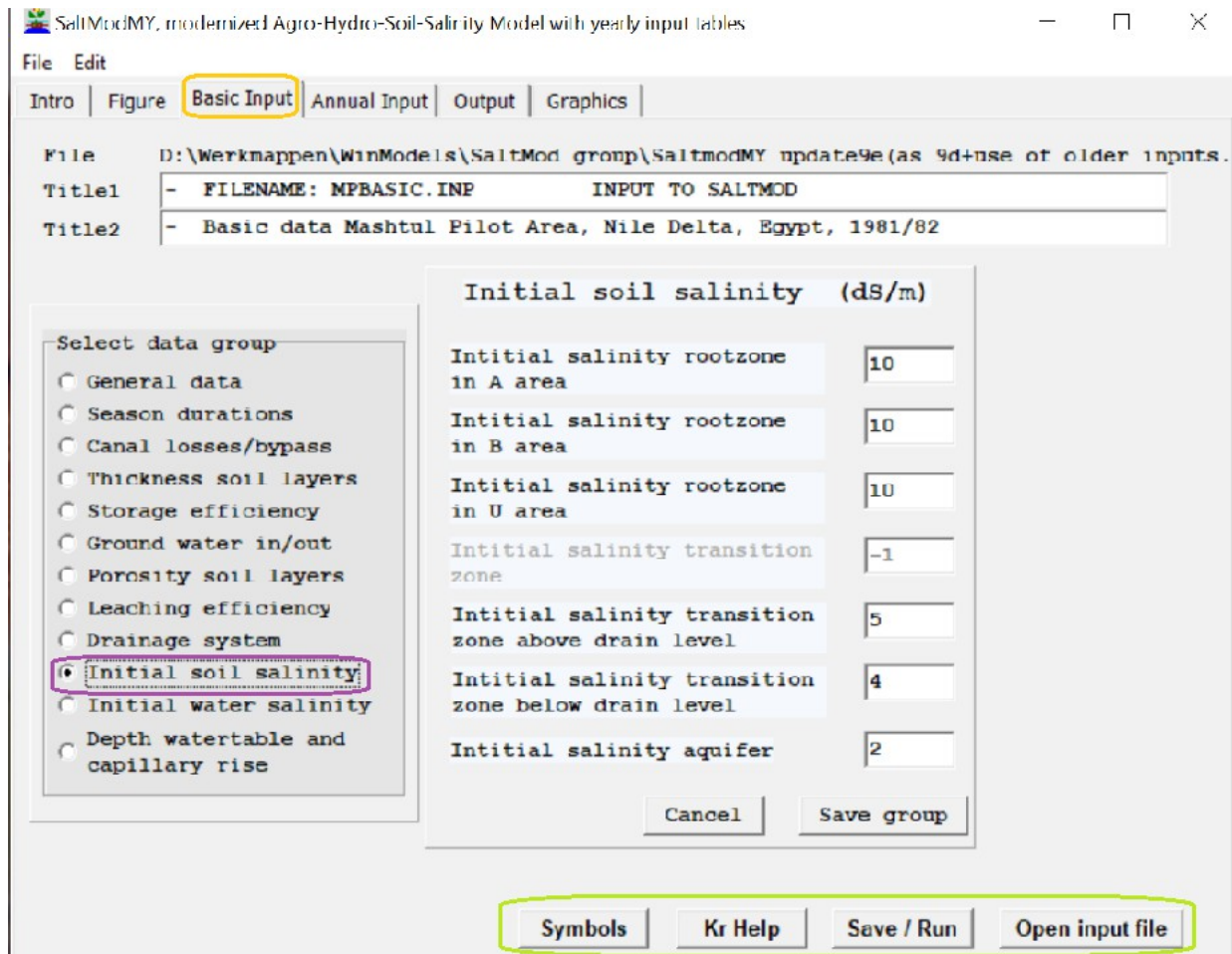
The basic input is revealed in figure 3.

Figure 3. The Basic Input worksheet (orange marker) demonstrating the initial soil salinity data (purple marker). As a subsurface drainage system is present in the transition zone, the initial salinity in this zone are differentiated between the parts above and below drain level. The buttons right under (green marker) show the possibilities to open another input file, to save this input file and run the program, to consult the details of the Kr index for farmers' responses, and to see the complete list of input symbols.

3. Output examples

SaltMod can give an overview of output groups that can be selected for use in Excel and for graphics (Fig. 4).
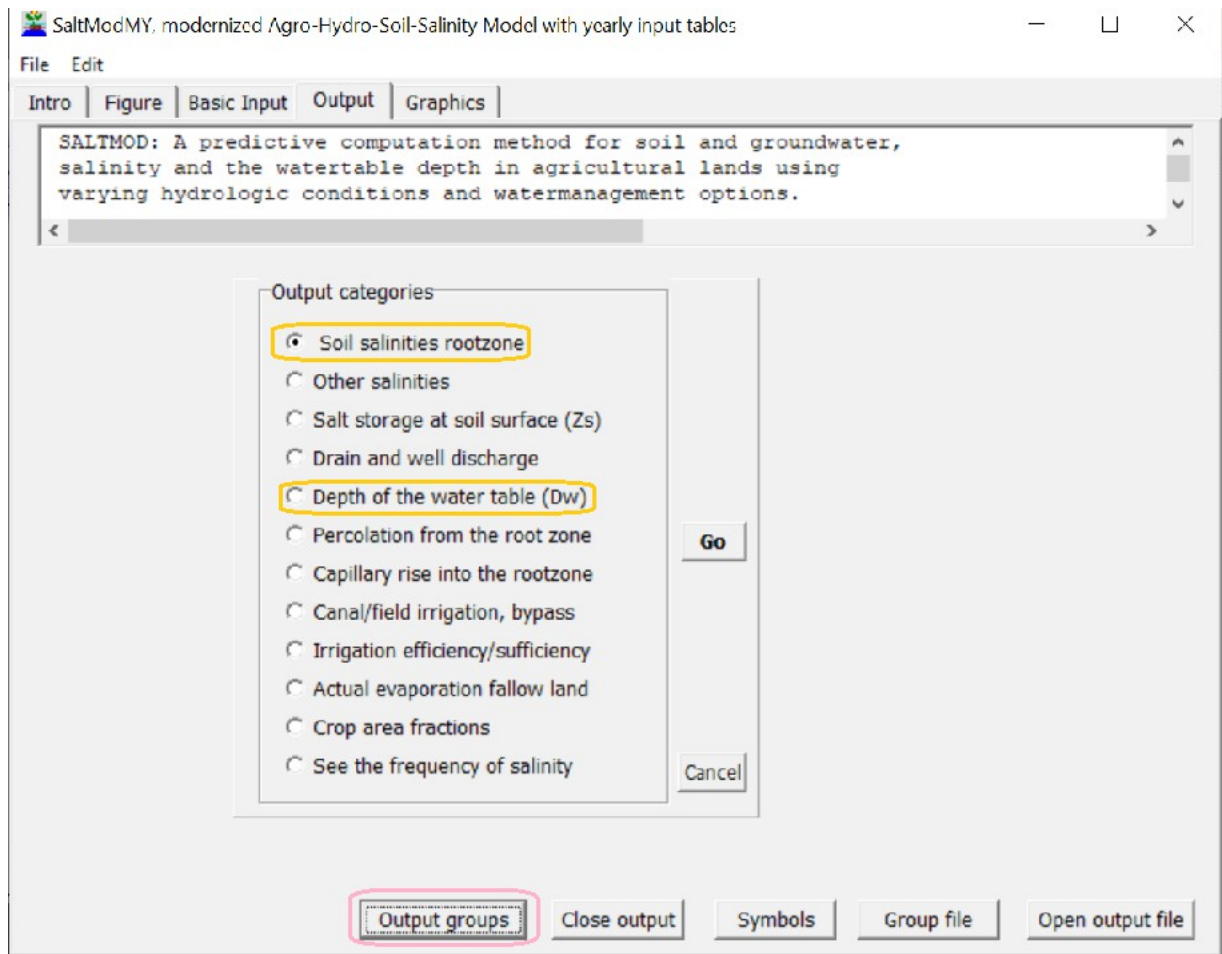
Figure 4. Overview of output groups (pink marker) in SaltMod. The rootzone salinity and the depth of the water table (yellow markers) will be used to show graphics.

Figure 5 shows a graph of the soil salinity of the root zone over the years and seasons, while Figure 6 picture the fluctuations of the water table. The data were obtained in the Mashtul pilot area in the Nile Delta, Egypt **[Ref. 5].**
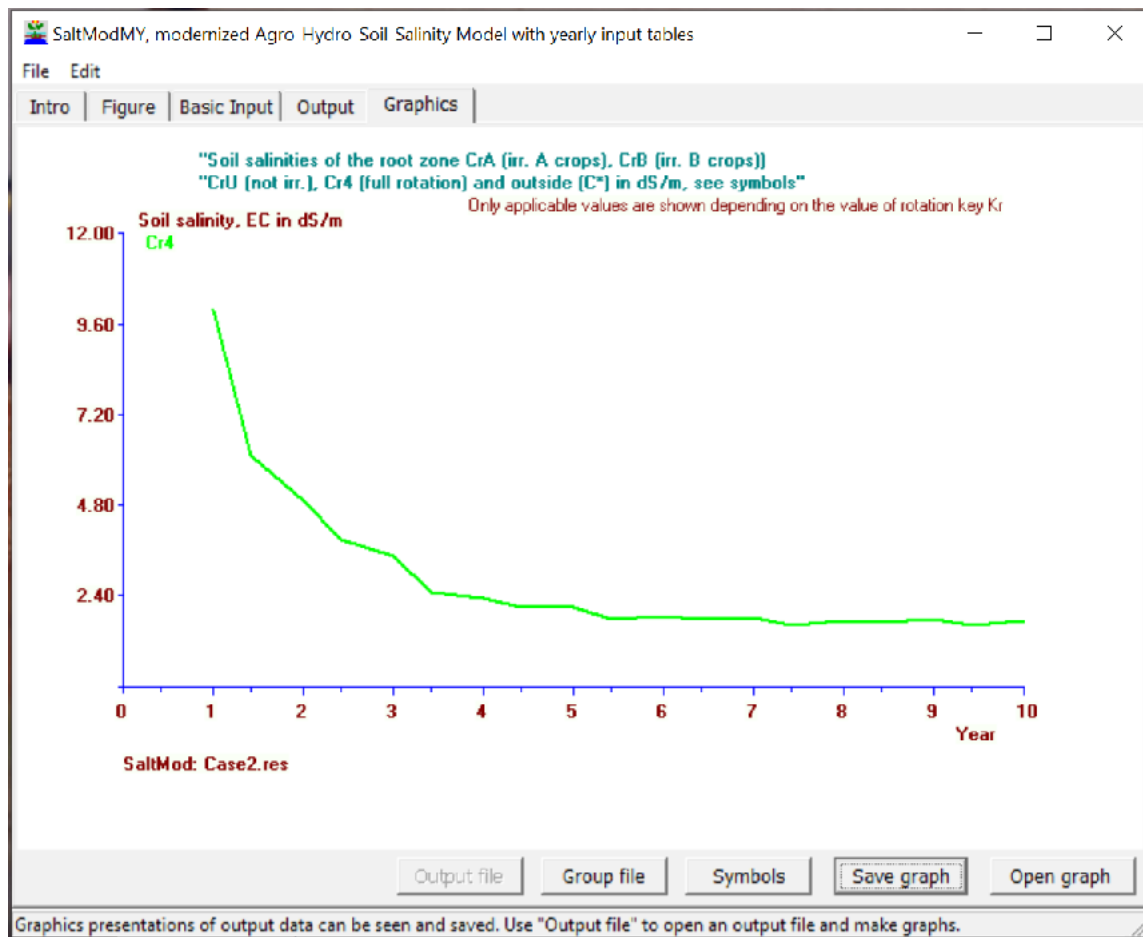
*Figure 5. Soil salinity of the root zone versus time. As the crop rotation index (Kr) equals 4, meaning that there is full rotation, the soil salinity taken as an average of all crops over all seasons (Cr4) as the crops continually change place, there are no fixed areas over time of either the A-type and B-type irrigated crops. The presence of a subsurface drainage systems helps to bring down the initially high soil salinity to a level acceptable for crop growth **[Ref. 6]***
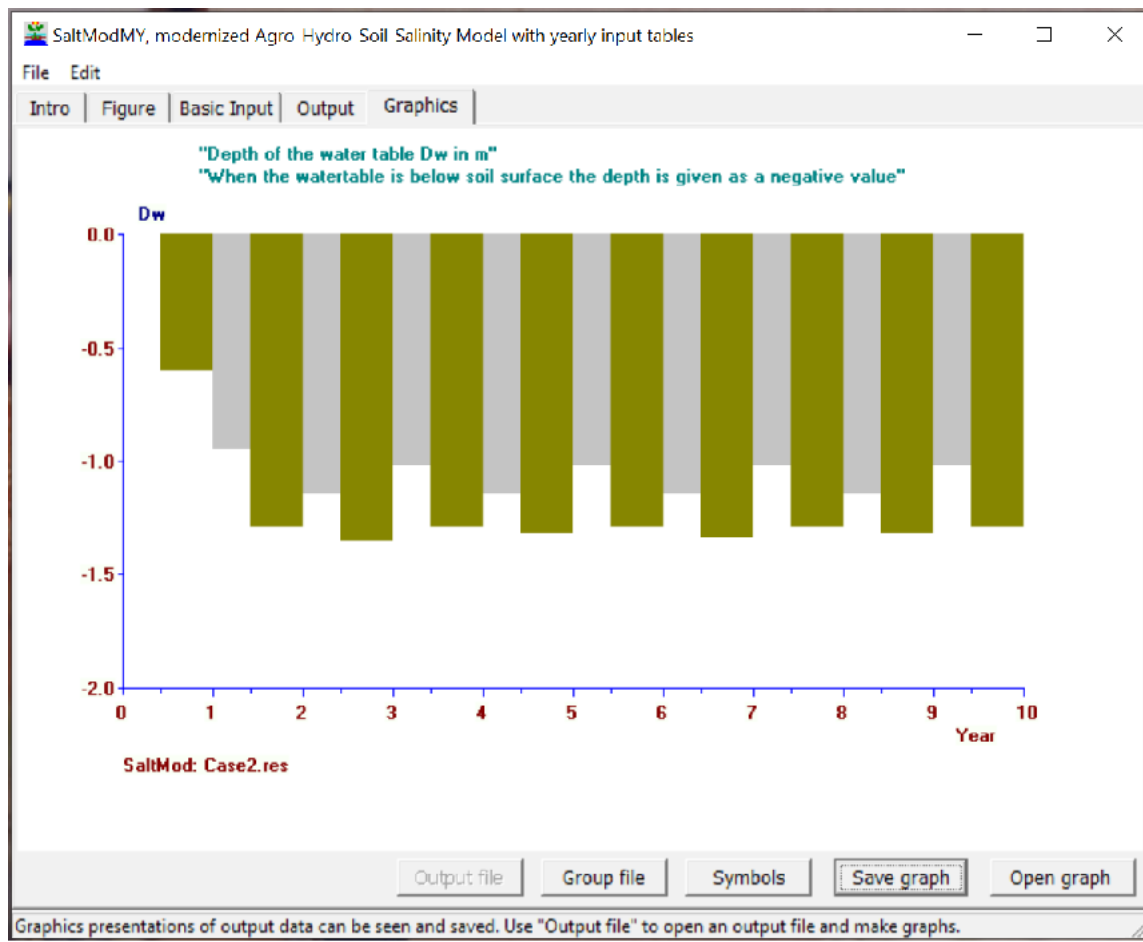
Figure 6. Seasonal depth of the water table over time. There are only two seasons per year. The subsurface drainage system has drawn the water table down to amply safe levels for crop growth [Ref. 7].

4. Conclusions

Although the classical Saltmod and the modernized SaltModM models give the option to interrupt calculations after each year to change certain input parameters that may be variable from year to year (rainfall is a clear example), the SaltModMY model streamlines this laborious method by offering the determination of the yearly variable factors in input tables, so that the program can perform all the calculations in one go.

5. References

[Ref. 1] List of journal articles in which SaltMod has been used. Download from:
https://www.waterlog.info/pdf/saltmodlist.pdf

[Ref 2] Download the SaltMod manual from: https://www.waterlog.info/pdf/saltmod.pdf
or from:
https://www.researchgate.net/publication/40186548_SALTMOD_description_of_principles_user_man
ual_and_examples_of_application_Version_11

[Ref. 3] SalModM, a modernized version of the free agro-hydro-soil-salinity model SaltMod.
Download from: https://www.waterlog.info/saltmod.htm

[Ref 4] SaltModMY, an updated version of SaltModM, allowing the introduction of annually seasonal
hydrological inputs so that the program does not need to tempoerarily hal ecah year to change the
values for the next run. Download freely from: https://www.waterlog.info/zip/SaltModMY.zip

[Ref. 5] R.J. Oosterbaan and M. Abu Senna, 1989. Using SaltMod to Predict Drainage and Salinity in
the Nile Delta. From Annual Report 1989, International Institute for Land Reclamation and
Improvement (ILRI), Wageningen, The Netherlands. Public domain. Download from:
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https://www.researchgate.net/publication/294780124_Using_SALTMOD_to_predict_drainage_and_sa
linity_in_the_Nile_Delta

[Ref. 6] R.J.O, 2018. Crop tolerance to soil salinity, statistical analysis of data measured in farm
lands. International Journal of Agricultural Science 3, 57-66. View at:
https://www.waterlog.info/pdf/AgrJournal.pdf
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https://www.researchgate.net/publication/332466260_CROP_TOLERANCE_TO_SOIL_SALINITY_
STATISTICAL_ANALYSIS_OF_DATA_MEASURED_IN_FARM_LANDS

[Ref. 7] R.J.O, 2019. Crop yield and depth of water table, statistical analysis of data measured in farm
lands. Download from: https://www.waterlog.info/pdf/Crop%20yield%20and%20depth%20of
%20water%20table.pdf
or from:
https://www.researchgate.net/publication/335260187_Crop_yield_and_depth_of_water_table_statistic
al_analysis_of_data_measured_in_farm_lands

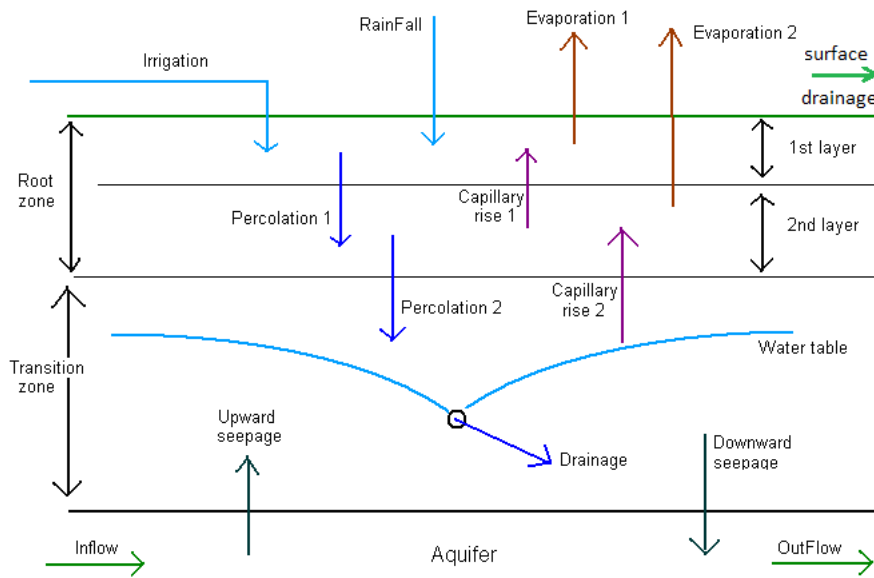**APPENDIX** Water and Salt Balance Equations Used in LeachMod

Figure A. Water balances of the soil in the presence of two root one layers. For a third layer the symbols used are similar.

1. Water Balances (flows in mm / time step, depths in m, see figure A):

First layer: Rain + Irrig + Cap1 = Perc1 + Evap1 + SurfDr

Second layer: Perc1 + Cap2 = Perc2 + Evap2

Third layer: Perc2 + Cap3 = Perc3 + Evap3

Transition zone: Perc3 + Upw = Drain + Cap3 + Down

Aquifer: Info + Down = Up + Out
                [*Down >= 0, Up >= 0*]

where Rain = rainfall, Irrig = Irrigation, Perc1 = Percolation from the 1st layer, Perc2 = Percolation from the 2nd layer, Perc3 = Percolation from the 3rd layer, Evap1 = Evapo-transpiration (actual) from the 1st layer, Evap2 = Evapo-transpiration (actual) from the 2nd layer, Evap3 = Evapo-transpiration (actual) from the 3rd layer, Cap1 = Capillary rise into the 1st layer, Cap2 = Capillary rise into the 2nd layer, Cap3 = Capillary rise into the 3rd layer, Drain = discharge of the subsurface drainage system, SurfDr = Surface drainage, Upw = Upward flow from the aquifer, Down = Downward flow into theaquifer, Inf = Horizontal inflow into the aquifer, Out = Horizontal flow out from the aquifer.

Specification of percolation and capillary rise per layer (when Perc>0 then Cap=0 and vice versa)

a - only one root zone layer present

    Perc1 = (Rain+Irrig) / IrrEff - Evap1
    Cap1 = CapT
    where IrrEff is the irrigation or storage efficiency
    and CapT is the total capillary rise from the
    water table (see below).

b - two root zone layers are present

    Perc1 = (Rain+Irrig) / IrrEff - Evap1
    Perc2 = Perc1 - Evap2
    Cap1 = CapT - Evap2
    Cap2 = CapT

c - three root zone layers are present

    Perc1 = (Rain + Irri) / IrrEff - Evap1
    Perc2 = Perc1 - Evap2
    Perc3 = Perc2 - Evap3
    Cap1 = Cap2 - Evap2
    Cap2 = Cap3 - Evap3
    Cap3 = CapT

Specification of actual evapo-transpiration per layer:

a - only one root zone layer is present:
    Evap1 = total actual evapo-transpitation (ETa)

b - two root zone layers of equal thickness:
    Evap1=2*ETa/3, Evap2=ETa/3

c - three root zone layers of equal thickness:
    Evap1=ETa/2, Evap2=ETa/3, Evap3=ETa/6

When the root zone layers are of unequal thickness, then adjustments are made on the basis of their relative thickness.

The total capillary rise and actual evapo-transpiration are calculated as:

    ETa = IrrEff*WR+CF*(EvapT-IrrEff*WR)
    CapT = EvapA-WR   *[CapT>=0]*

where EvapT is the potential evapo-transpiration, WR is the surface water resources and CF is a capillary rise factor, determined as:

WR = Irrig + Rain
CF = (CDc − Dwt)/CDw   [0 < CF <1]

where Dwt (m) is the depth of the water table and CDc (m) is the critical depth of the water table for capillary rise.

The drain discharge is determined as:

DRa = QH1*(Dd-Dwt)^2
DRb = QH2*(Dd−Dwt)
Drain = DRa + DRb

where DRa is amount of drainage water originating from the soil above drain level, Drb is amount of drainage water originating from the soil below drain level, Dd is the drain depth (m), Dwt is the depth of the water table (m), QH1 is the reaction factor of the drainage system for flow above drain level (mm/m^2 per day), and QH2 is the reaction factor of the drainage system for flow below drain level (mm/m per day).

The depth of the water is calculated as:

$$\text{Dwt} = \frac{\text{Dwp - Ts*(Perc3−CapT−Drain+Up−Down)}}{100*\text{EffPor}}$$

where Dwp is Dwt of the previous time step, Ts is the duration of the time step (day), and EffPor is the effective or drainable porosity (%) of the soil
layer in which the water table is situated.

Salt Balances (salinity in dS/m at field saturation)

1. Root zone with only one layer

1a - Root zone salt balance:

Sin = Irri*Si + Cap1*STr
Sout = LEr*Perc1*SRa/100 + SurfDr*Ssd
SRo = SRp + (Sin−Sout)/Wr

where, additionally, Sin is incoming salt, Sout is outgoing salt, Si is the salinity of the irrigation water, Ssd is the salinity of the surface drainage, STr is the salinity of the transition zone, LEr is the leaching efficiency (%) of the root zone, SRo is the salinity of the root zone, SRp is SRo of the previous time step, SRa is the average of Sro and SRp, and Wr is the amount of water stored in the root zone, equal to:

Wr = Dr*TPr/100

where Dr is the depth of the root zone and TPr is the total porosity (%) of the root zone.

1b - Transition zone salt balance:

$$Sin = LEr*Perc1*SRa/100 + Up*SAq/100$$
$$Sout = LEt*(Drain+Down+Cap1)*STa/100$$
$$STr = STp + (Sin-Sout)/Wt$$

where, additionally, SAq is the salinity of the aquifer, LEt is the leaching efficiency (%) of the transition zone, STp is STr of the previous time step, STa is the average of STr and STp, and Wt is the amount of water stored in the transition zone, equal to:

$$Wt = Dt*TPt/100$$

where Dt is the depth of the transition zone and TPt is the total porosity (%) of the transition zone.

1c - Aquifer salt balance:

$$Sin = LEt*Down*STa/100 + Inf*Sinf/100$$
$$Sout = LEa*(Up+Out)*SAa/100$$
$$SAq = SAp + (Sin-Sout)/Wa$$

where, additionally, LEa is the leaching efficiency (%) of the aquifer, Sinf is the salt concentration of Inf, SAp is SAq of the previous time step, SAa is the average of SAq and SAp, and Wa is the amount of water stored in the aquifer, equal to:

$$Wa = Da*TPa/100$$

where Da is the depth of the aquifer and TPa is the total porosity (%) of the aquifer.

2. Root zone with two layers

2a - First layer salt balance:

$$Sin = Irri*Si + Cap1*S2$$
$$Sout = LE1*Perc1*S1a/100 + SurfDr*Ssd$$
$$S1 = S1p + (Sin-Sout)/W1$$

where S1 is the salinity of the first layer, S2 is the salinity of the second layer, S1p is S1 of the previous time step, S1a is the average of S1 and S1p, and W1 is the amount of water stored in the first layer, equal to:

$$W1 = D1*TP1/100$$

where D1 is the depth of the first layer and TP1 is the total porosity (%) of the first layer.

2b - Second layer salt balance:

Sin = LE1*Perc1*S1a/100 + Cap2*STr/100
Sout = LE2*(Perc2+Cap1)*S2a/100
S2 = S2p + (Sin−Sout) /W2

where, additionally, LE2 is the leaching efficiency (%) of the second layer, STp is STr of the previous time step, S2a is the average of S2 and S2p, and W2 is the amount of water stored in the second layer, equal to:

W2 = D2*TP2/100

where D2 is the depth of the second layer and TP2 is the total porosity (%) of the second layer.

2c - Transition zone salt balance:

Sin = LE2*Perc2*S2a/100 + Up*SAq/100
Sout = LEt*(Drain+Down+CapT)*STa/100
STr = STp + (Sin−Sout)/Wt

2d - The salt balance of the aquifer remains unchanged.

3. Root zone with three layers

3a- The salt balance of the first layer is the same as that of the first layer in the two layer case.

3b - Second layer salt balance

Sin = LE1*Perc1*S1a/100 + Cap2*S3/100
Sout = LE2*(Perc2+Cap1)*S2a//00
S2 = S2p + (Sin−Sout)/W2

3c - Third layer salt balance:

Sin = LE2*Perc2*S2a/100 + Cap3*STr/100
Sout = LE3*(Perc3+Cap2)*S3a/100
S3 = S3p + (Sin−Sout) /W3

where, additionally, LE3 is the leaching efficiency (%) of the third layer, S3 is the salinity of the third layer, S3p is S3 of the previous time step, S3a is the average of S3 and S3p, and W3 is the amount of water stored in the third layer, equal to:

W3 = D3*TP3/100

where D3 is the depth of the third layer and TP3 is the total porosity (%) of the third layer.

3d - Transition zone salt balance:

$$Sin = LE3*Perc3*S3a/100 + Up*SAq/100$$
$$Sout = LEt*(Drain+Down+CapT)*STa/100$$
$$STr = STp + (Sin-Sout)/Wt$$

3e - The salt balance of the aquifer remains unchanged.

4. Salinity of the subsurface drainage water

$$Sdr = (LEt*DRa*Str + LEa*DRb*Saq)/Drain$$

where the symbols used are as defined before.