

Manual of the free DrainApp model for subsurface drainage systems with emphasis on their response functions, behavior of the groundwater table, and simulation of soil salinity in 5 soil layers optimizing their leaching efficiency.

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Abstract

DrainApp is designed to simulate the depth of the water table and the soil salinity in irrigated areas with a time step as selected by the user (from 1 day to 1 year). In case of a leaching experiment with measured soil salinities, DrainApp can automatically optimize the leaching efficiency by minimizing the sum of the squares of the differences between measured and simulated salinities, if the user permits. The root zone can consist of 1, 2, or 3 layers. DrainApp allows the introduction of a subsurface drainage system in a transition zone between root zone and aquifer, and subsequently it determines the drain discharge as well as the depth of the water table. In the presence of measured discharges and/or depths of the water table, DrainApp will optimize the capacity of the drainage system, if so desired by the user. When the irrigation and rainfall are scarce and the water table is still shallow, DrainApp will calculate the capillary rise and reduce the potential evapotranspiration to an actual evapotranspiration. DrainApp can also take into account upward seepage from the aquifer or the downward natural drainage into it.

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1. Introduction

The DrainApp (*Reference 1*) model has similarity to the LeachMod model (*Reference 2*). However, the first emphasizes the hydraulics of the drainage system. The LeachMod model has been recommended in India (*Reference 3*) and applied in Peru (*Reference 4*).

The model is designed for practical use and asks for data that are usually available or that can be estimated confidentially from experience. It does not use complicated equations for unsaturated groundwater flow, like the Richards equation, as unsaturated flows like downward percolation or upward capillary rise can be derived from simple water balances.

2. Main menu

When downloading the free DrainApp model and clicking on DrainApp.exe for a start, the following picture appears on the screen.

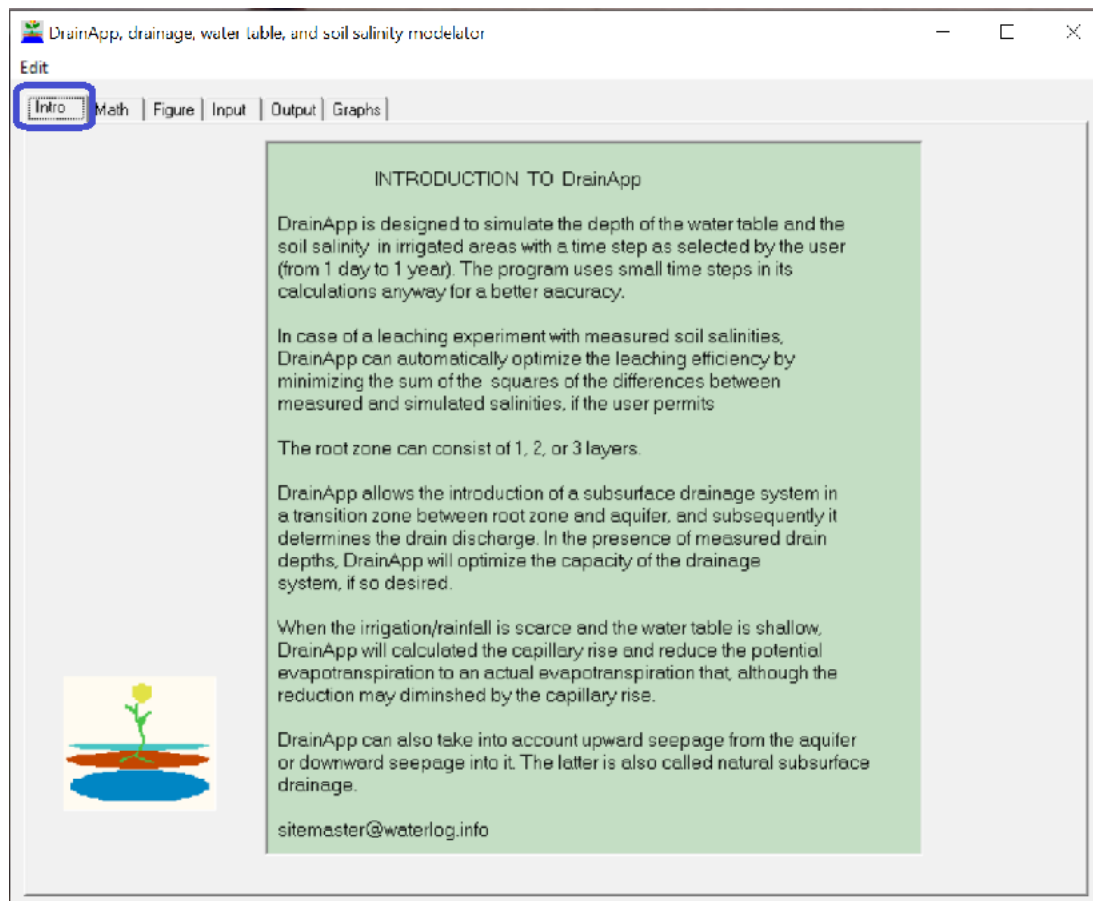


Figure 1. *Intro* tab sheet of DrainApp (blue square). Here a summary is given of the model possibilities. The other tab sheets that can be opened are those presenting the mathematics (see *Math* tab), the *Figure* tab illustrating the water flows, the *Input* tab, the *Output*, and the *Graphics* tabs as can be seen top-left.

Figure 2 clarifies the necessary general data to be entered in the input tab sheet of the model. *Figure 3* shows part of the mathematics tab sheet, to see more of the contents, one needs to scroll down using the scroll bar.

Figure 4 depicts a figure indicating the hydrological factors used in the model for the water balances. It shows 2 soil layers above drain level (although 3 layers are also possible), while the drains are found in the transition zone below which the aquifer is situated.

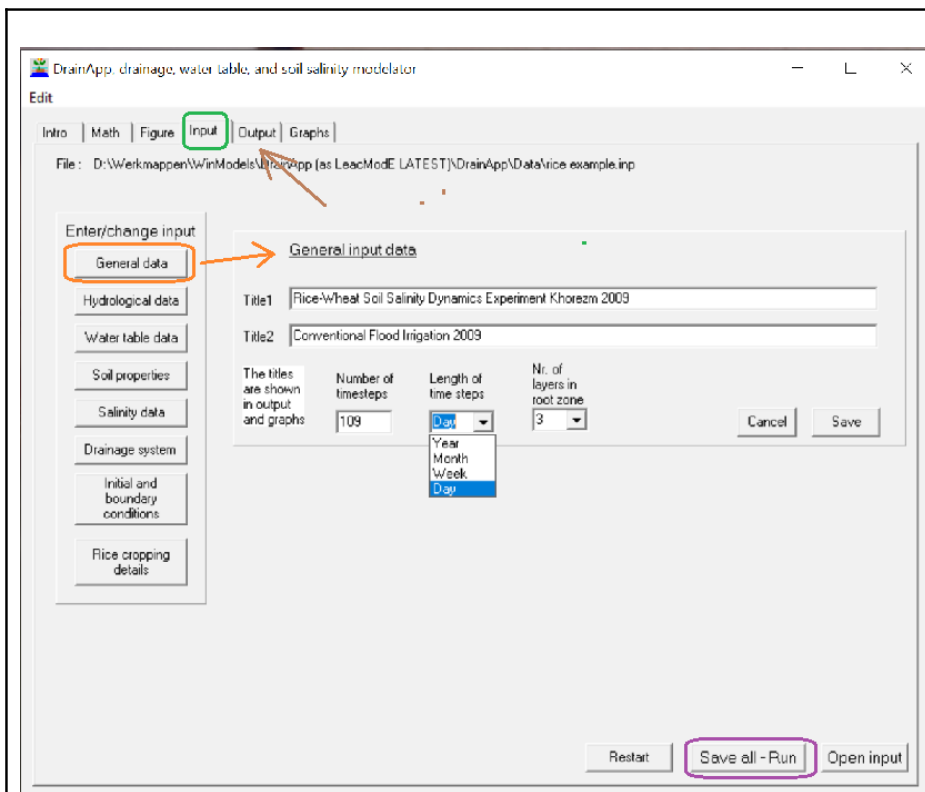


Figure 2. Picture of the input tab sheet (green square). Details of the general data can be seen and changed after clicking on the “General data” button (orange square). Here specifications can be given on the number of time steps, the length of the time step (blue selection box) and the number of layers in the root zone (1, 2 or 3). The “Save-all-Run” button (green square) gives rise to the calculations and appearance of the output menu (brown arrow).

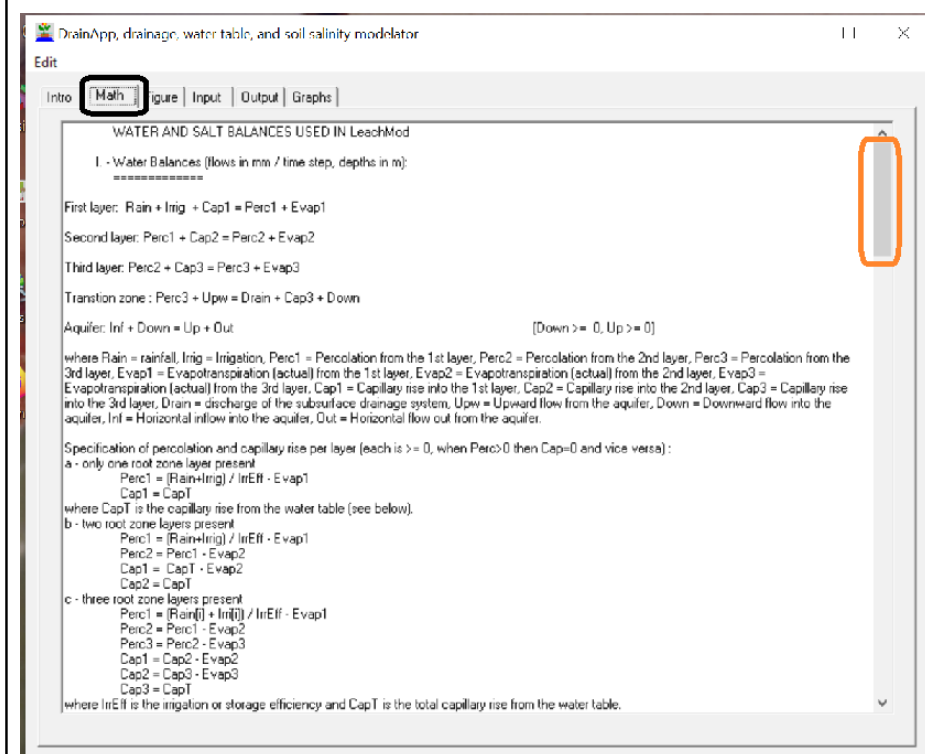


Figure 3. Top part of the mathematics tab sheet (blue square) describing all the equations used in DrainApp. To see more, one needs to scroll down using the scroll bar (orange square).

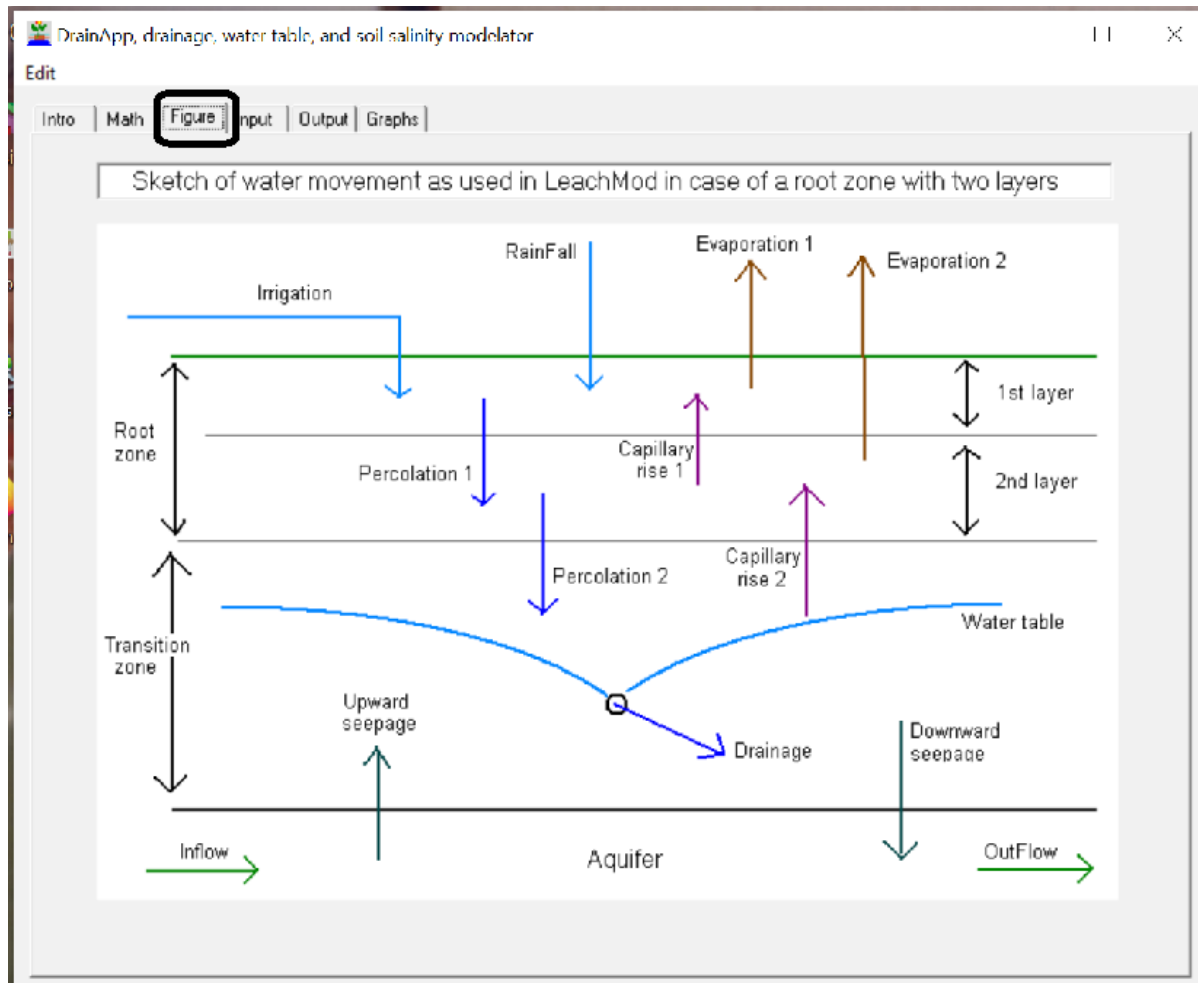


Figure 4. This Figure tab sheet (black square) illustrates the hydrological and water balance components. The picture shows 2 soil layers above drain level (although 3 layers are also possible), while the drains are found in the transition zone below which the aquifer is situated.

2. Input menu

Figure 5 specifies the hydrological data per time step (rainfall, irrigation, potential evaporation and surface drainage) that are required to be known in the model.

Figure 6 gives a table in which the measured soil salinity values in the root zone layers, the transition zone and the aquifer, if any, can be entered. When measured data are not available, the corresponding table compartments are to be left blank. Availability of measured salinity values provides the opportunity to optimize the salt leaching efficiency and to show both the simulated and the measured salinity values in the graphs that can be made with DrainApp.

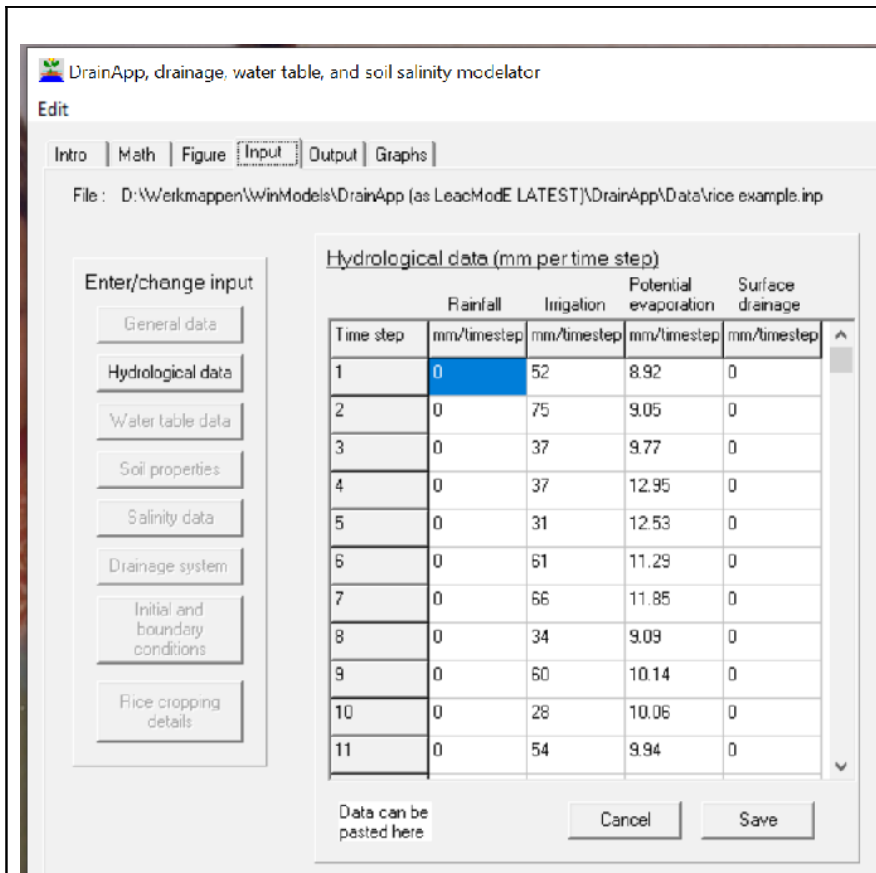


Figure 5.

Under the selection button “Hydrological data” a table is given to fill in the rainfall, irrigation, potential evaporation and surface drainage data per time step. If desired, the data can be pasted from the clipboard, for example after selecting data in Excel and giving there the “copy” command

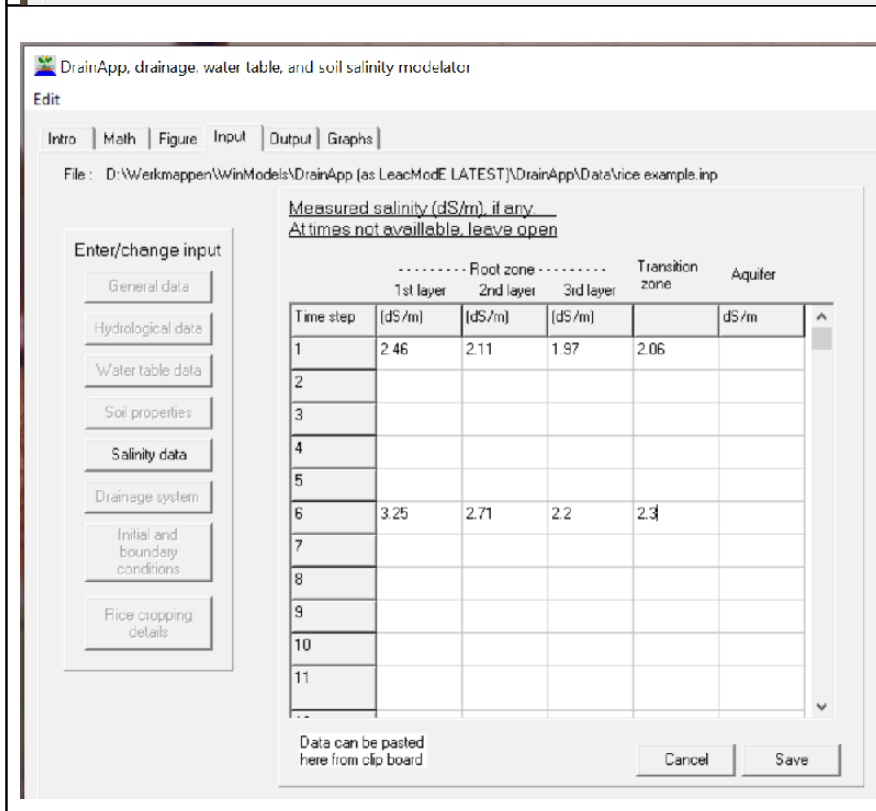


Figure 6. When clicking on the “Salinity data” selection button, a Table is given in which the measured soil salinity values in the root zone layers, the transition zone and the aquifer, if any, can be entered. When measured data are not available, the corresponding table compartments are to be left blank. Availability of measured salinity values provides the opportunity to optimize the salt leaching efficiency and to show both the simulated and the measured salinity values in the graphs that can be made with DrainApp.

For water table data (see the third selection button) a similar procedure is followed. Availability of measured salinity values provides the opportunity to optimize the subsurface drainage response function, if so desired, and to show both the simulated and the measured water table values in the graphs that can be made with DrainApp.

The determination of the response function is explained in *figure 7*, while the relevant subsurface drainage equations are shown in *figure 8*.

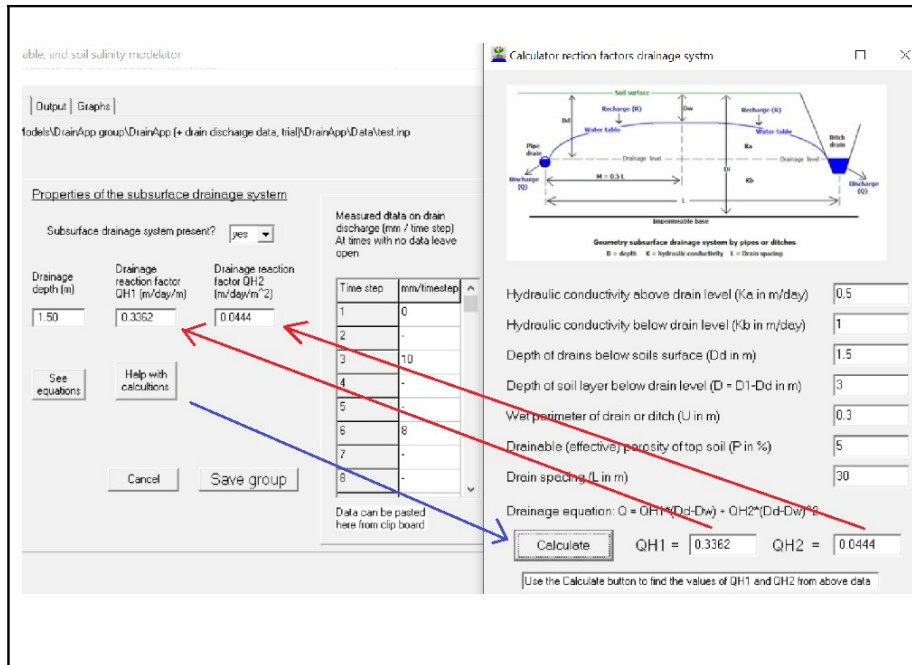


Figure 7.

Clicking on the link “Drainage system” (see figure 2) produces the left hand image. Clicking here on the button “Help with calculations” makes the right hand calculation sheet visible (blue arrow). Completing here all the data and clicking “Calculate” creates the QH1 and QH2 response factors (orange arrows).

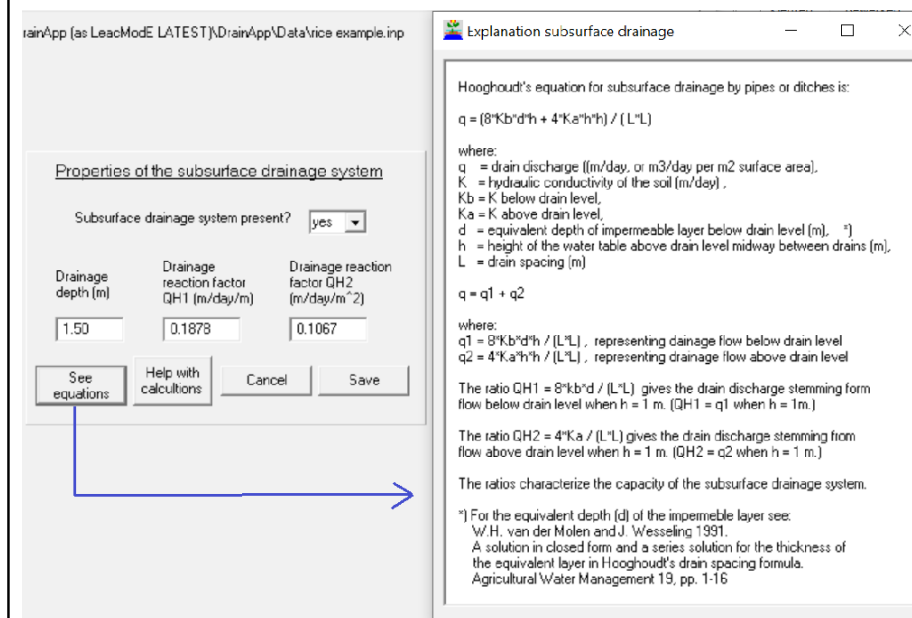


Figure 8.

Clicking on the “See equations” link produces the right hand image with the drainage equation used and explanation of the symbols employed.

3. Output menu

Figure 9 makes it clear that the output menu is opened (brown square) after having done the calculation using the “Save–Run” button in the input menu (figure 2). In this example the soil salinity output has been selected (orange cross). It would also be possible to open the hydrological output (blue arrow). The result is demonstrated in figure 10. The output data can be copied to the clipboard (green arrow), for example to paste the output and do further analysis in Excel. In case the user wishes to see the graphics, he /she may click the “See graphs” button (purple square).

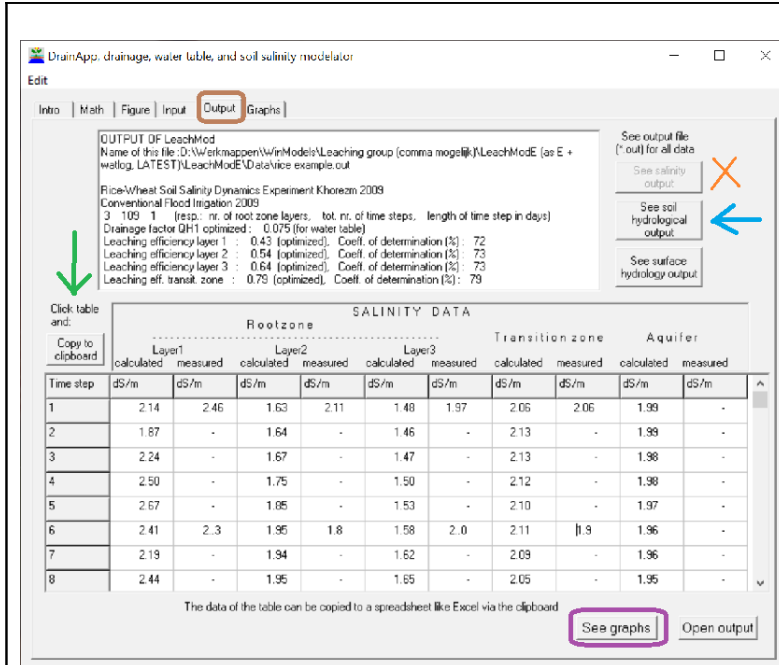


Figure 9.

For the description see the above explanation.

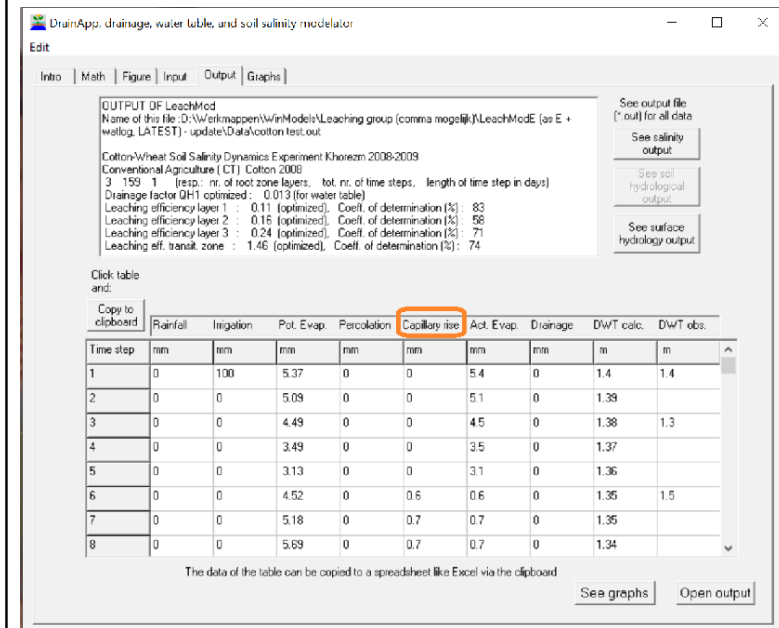


Figure 10.

As figure 9 with the difference that here the hydrological output is shown instead of the soil salinity output.

The orange square points to the capillary rise of the ground water trough the water table. As the rainfall and irrigation are scarce, the root zone dries out an it sucks the groundwater up. As the water flowing upwards will evaporate, the salts carried with it will precipitate.

An example of a capillary rise graph is given in figure 11.

Figure 11 gives an enlargement of the top of the output sheet shown in the previous two figures. Here it can be seen that the Drainage factor QH1 has been optimized to 0.0003 (while the given QH1 value is 0.100), in order to obtain a maximum fit of the calculated depths of the water table to the measured depths. Further the leaching efficiency in the root zone (layer 1) has been optimized to obtain the maximum fit of the calculated (simulated) soil salinities to the measured ones. Hence, it differs from the given efficiency in the input. The goodness of fit (coefficient of determination) is 93% (green circle).

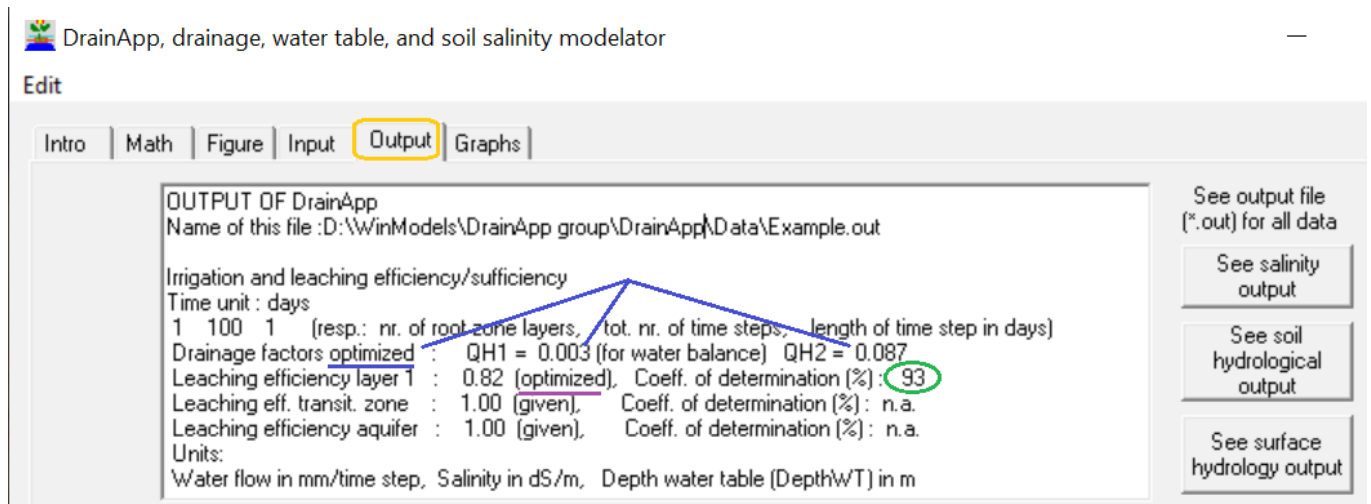


Figure 11. Enlargement of the top part of the output sheet as shown in the previous two figures. The drainage factor $QH1$ has been optimized to 0.003 and $QH2$ to 0.087 (blue lines). The leaching efficiency in the root zone (layer 1) has also been optimized (purple underscore). At the right hand side the selection options for viewing output data are more clearly visible.

Figure 12 visualizes the behavior of the subsurface hydrological factors in time. The factors shown are downward percolation (blue), upward capillary rise (red), and subsurface drainage (yellow).

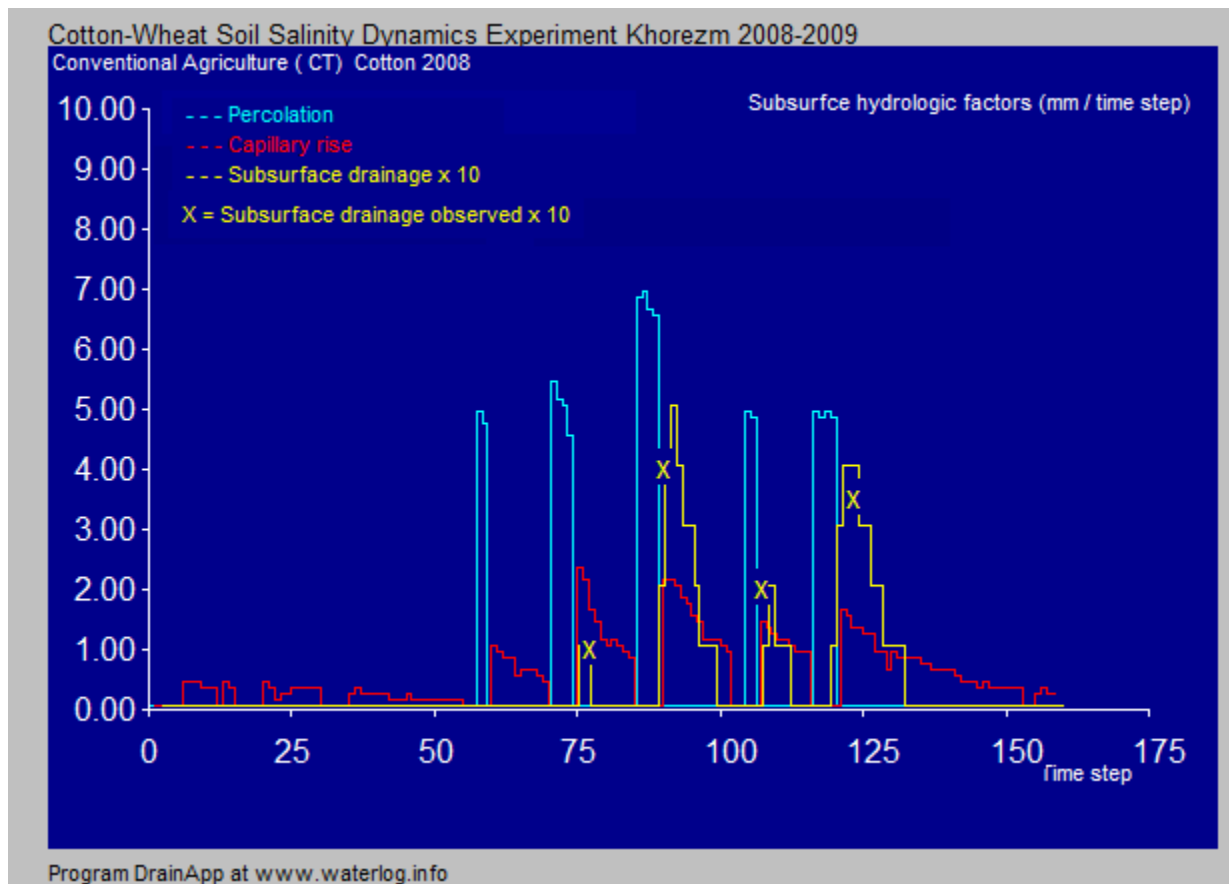


Figure 12. Behavior of the subsurface hydrological factors in time. The factors shown are downward percolation (blue), upward capillary rise (red), and subsurface drainage (yellow) as well as the observed discharges (yellow crosses). The percolation sets in after each irrigation. This will cause the water table to rise which is followed by subsurface drainage. When the percolation has stopped, the root zone will dry out and suck up the water from the water table by capillary rise. This, together with the subsurface drainage will drop, which reduces both the subsurface drainage and the capillary rise. After another irrigation, the processes will be repeated.

After confirming the “See graphs” link (figure 9, purple square), a graphics selection menu becomes visible (figure 13).

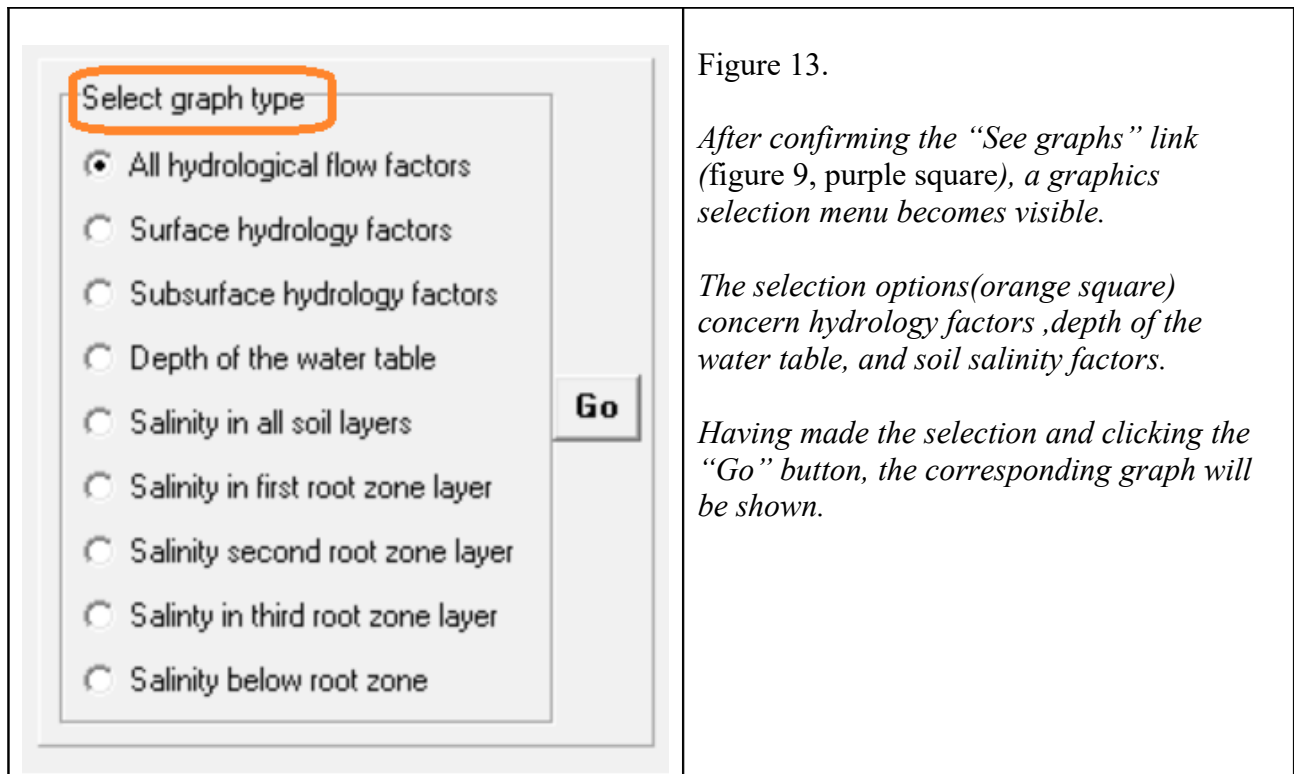


Figure 13.

After confirming the “See graphs” link (figure 9, purple square), a graphics selection menu becomes visible.

The selection options (orange square) concern hydrology factors, depth of the water table, and soil salinity factors.

Having made the selection and clicking the “Go” button, the corresponding graph will be shown.

The following two figures give output graphs in which the simulated and measured values of the water table depth (*figure 14*) and the soil salinity of the second soil layer (*figure 15*).

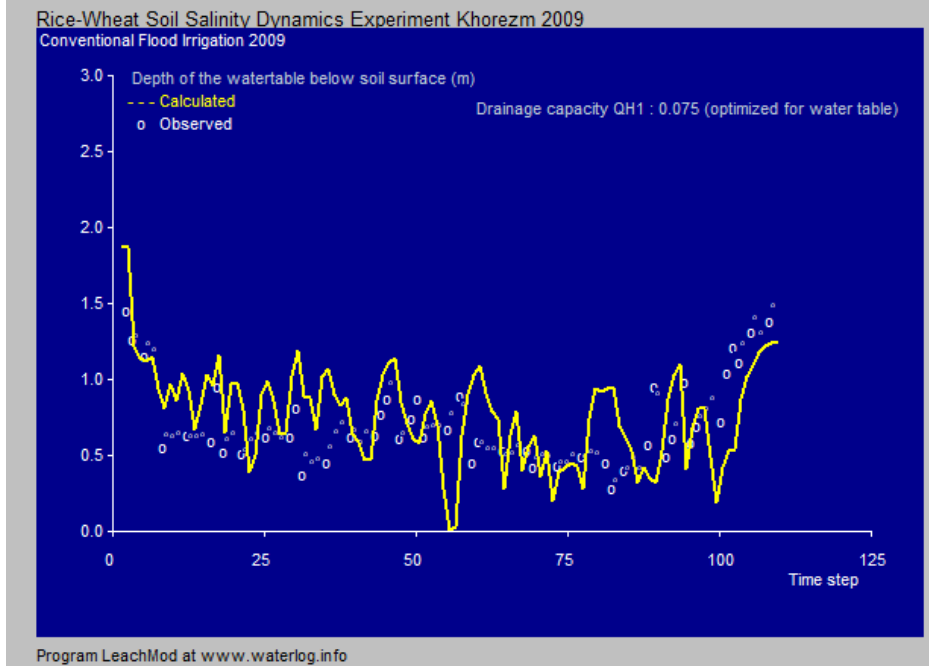


Figure 14

Simulated time trend of the depth of the water table (yellow) and observed values (circles).

The response factor QH1 of the subsurface drainage system is optimized to 0.075 in order to obtain the best possible fit.

The water table fluctuates in time, but the average trend after the start and just before the end is between 0.6 and 0.8 m

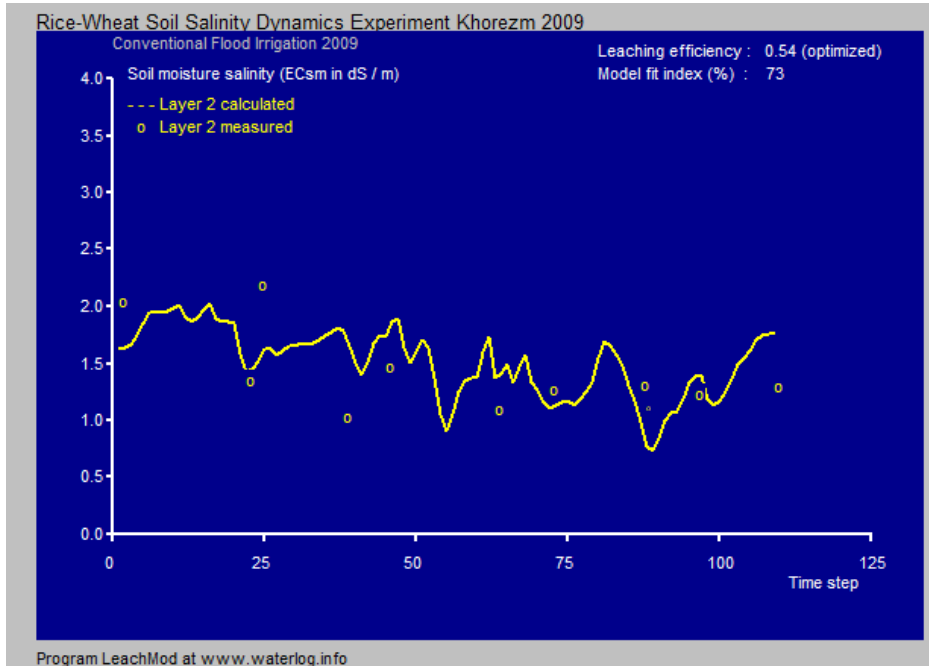


Figure 15

Simulated time trend of the depth of the water table (yellow) and observed values (circles) in the 2nd root zone layer.

The salt leaching efficiency is optimized to 0.54 in order to obtain the best possible fit.

Though the salinity varies in time, the average trend overall is an ECsm between 1.3 and 1.7 dS/m, ECsm being the ECE of the soil moisture.

4. Conclusions

The DrainApp model has an input menu that is easy to handle and it does not contain complicated data that are difficult to establish, like the unsaturated hydraulic conductivity and the Richard's equation. Data can be pasted from the clipboard so that they can be entered by copying them from a spreadsheet program like Excel.

Similarly, the output menu is easy to handle and it provides the possibility to copy the data to the clipboard so that they can be pasted into a spreadsheet program like Excel for further elaboration. Also it can produce graphs that are helpful to interpret the results.

The program offers the possibility to optimize subsurface drainage reaction (response) factors and the salt leaching efficiency if so desired by the user and on condition that observed values of the depth of the water table and/or of the soil salinity are available.

The subsurface drainage response factors can be calculated by DrainApp on the basis of the common parameters of the subsurface drainage system.

5. References

Reference 1.

DrainApp, free software for subsurface drainage calculations, water table and soil salinity. Download from: <https://www.waterlog.info/zip/DrainApp.zip>

Reference 2.

LeachMod, free software for soil salinity simulation using a leaching efficiency and water and salt balances. Download from: <https://www.waterlog.info/zip/LeachMod.zip>

Reference 3.

S.K. Gupta et al., 2019. *Innovations in Agricultural & Biological Engineering*. Apple Academic Press Inc. https://books.google.nl/books?id=ZfiCDwAAQBAJ&pg=PT29&lpg=PT29&dq=LeachMod&source=bl&ots=CzCoA86dDx&sig=ACfU3U3I0_qGh8QgYT0jdexauRvs4YHn6w&hl=nl&sa=X&ved=2ahUKEwjzqa39tZv2AhXqMuwKHb39A0gQ6AF6BAgfEAM#v=onepage&q=LeachMod&f=false

Reference 4.

R. J. Oosterbaan. (2019) *Reclamation of a Coastal Saline Vertisol by Irrigated Rice Cropping, Interpretation of the Data with a Salt Leaching Model*. International Journal of Environmental Science, 4, 48-60 <https://www.iasr.org/iasr/home/cajjes/reclamation-of-a-coastal-saline-vertisol-by-irrigated-rice-cropping-interpretation-of-the-data-with-a-salt-leaching-model>