Computer modeling in irrigation and drainage for the control of water logging and soil salinization in agricultural lands in India using SaltMod's modernized version SaltModM

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Abstract
In the conference paper of the Central Soil Salinity Research Institue (Karnal, Haryana) and Alterra (Wageningen, the Netherlands), published in 2002, the original version of SaltMod was used to assess water logging and soil salinity in the experimental fields of Sampla (Haryana), Gohana and Lakhuwali (Rajastan), Uppugunduru and Konanki (Andhra Pradesh), Upper Krishna and Tungabdadra command areas (Karnataka). See the reference. In this paper. the modernized version (SaltModM) will be applied using the same data and it will be shown that the results are the same. The main advantage of SaltModM is the improvement of the input menu making the operation more clear. Apart from SaltMod, also the models SWAP and UNSATCHEM were tested. It was observed, however, that to extend their use to other sites would require dedicated efforts in assembling the input data. On the other hand, the SALTMOD is based on simplified concepts and are therefore, less demanding on inputs. It was concluded that SALTMOD is a very useful tool for prediction of salinity of soil water, groundwater and drainage water, the depth of the water table and the drain discharge in irrigated agricultural land under varying water management options. Its simplicity of operation and minimal requirement of data that are generally available should help in promoting its use by the engineers to obtain the results that could be useful for the planners.

Contents

1. Introduction

SaltMod is computer program for the prediction of the salinity of soil moisture, ground water and drainage water, the depth of the water table, and the drain discharge in irrigated agricultural lands, using different (geo)hydrologic conditions, varying water management options, including the use of ground water for irrigation, and several cropping rotation schedules.

The water management options include irrigation, drainage, and the use of subsurface drainage water from pipe drains, ditches or wells for irrigation.

The computer program was originally made in Fortran by R.J. Oosterbaan and Isabel Pedroso de Lima at ILRI. A user shell in Turbopascal was developed by H. Ramnandanlal, and improved by R.A.L. Kselik of ILRI, to facilitate the management of input and output data.
Now, a Windows version is available, written in Delphi by Oosterbaan.

The program was designed keeping in mind a relative simplicity of operation to promote its use by field technicians and project planners. It aims at using input data that are generally available, or that can be estimated with reasonable accuracy, or that can be measured with relative ease. SaltMod has been used and tested extensively. A selection of reports and publications on the use of SaltMod is given in *Reference 2*.

A combination of SaltMod with a polygonal groundwater model (SahysMod) is also available, see http://www.waterlog.info/sahysmod.htm

Most of the computer models available for water and solute transport in the soil (e.g. Swap, Swatre, Drainmod) are based on Richard's differential equation for the movement of water in unsaturated soil in combination with a differential salinity dispersion equation. The models require input of soil characteristics like the relation between unsaturated soil moisture content, water tension, hydraulic conductivity and dispersivity. These relations vary to a great extent from place to place and are not easy to measure. The models use short time steps and need at least a daily data base of hydrologic phenomena. Altogether this makes model application to a fairly large project the job of a team of specialists with ample facilities.

There is a need for a computer program that is easier to operate and that requires a simpler data structure. Therefore, the SaltMod program was designed keeping in mind a relative simplicity of operation to promote its use by field technicians, engineers and project planners. It aims at using input data that are generally available, or that can be estimated with reasonable accuracy, or that can be measured with relative ease. Although the calculations are done numerically and have to be repeated many times, the final results can be checked by hand using the formulas in this manual.

The SWAP and the UNSATCHEM, being physically based models, besides practical applications had strong advantages in understanding the physical processes. It was observed however, that to extend their use to other sites would require dedicated efforts in assembling the input data. On the other hand, the SALTMOD is based on simplified concepts and are therefore, less demanding on inputs [*Reference 1*].

SaltMod aims at predicting the long-term hydro-salinity in terms of general trends, not in exact predictions of how, for example, the situation would be on the first of April in ten years from now. It is a specialty of SaltMod that the user can define the relevant cropping pattern and the crop rotation practices for which the calculations are specifically performed.

Further, SaltMod gives the option of the re-use of drainage and well water and it can account for farmers' responses to water logging, soil salinity, water scarcity and over-pumping from the aquifer. Also it offers the possibility to introduce subsurface drainage systems at varying depths and with varying capacities so that they can be optimized.

Figure 1 gives a picture of the some of the hydrological factors considered in Saltmod and it concerns two neighboring area A and B with different irrigated crops while the soil is divided into three layers. The button "Symbols list" helps in finding the definitions of the symbols used.

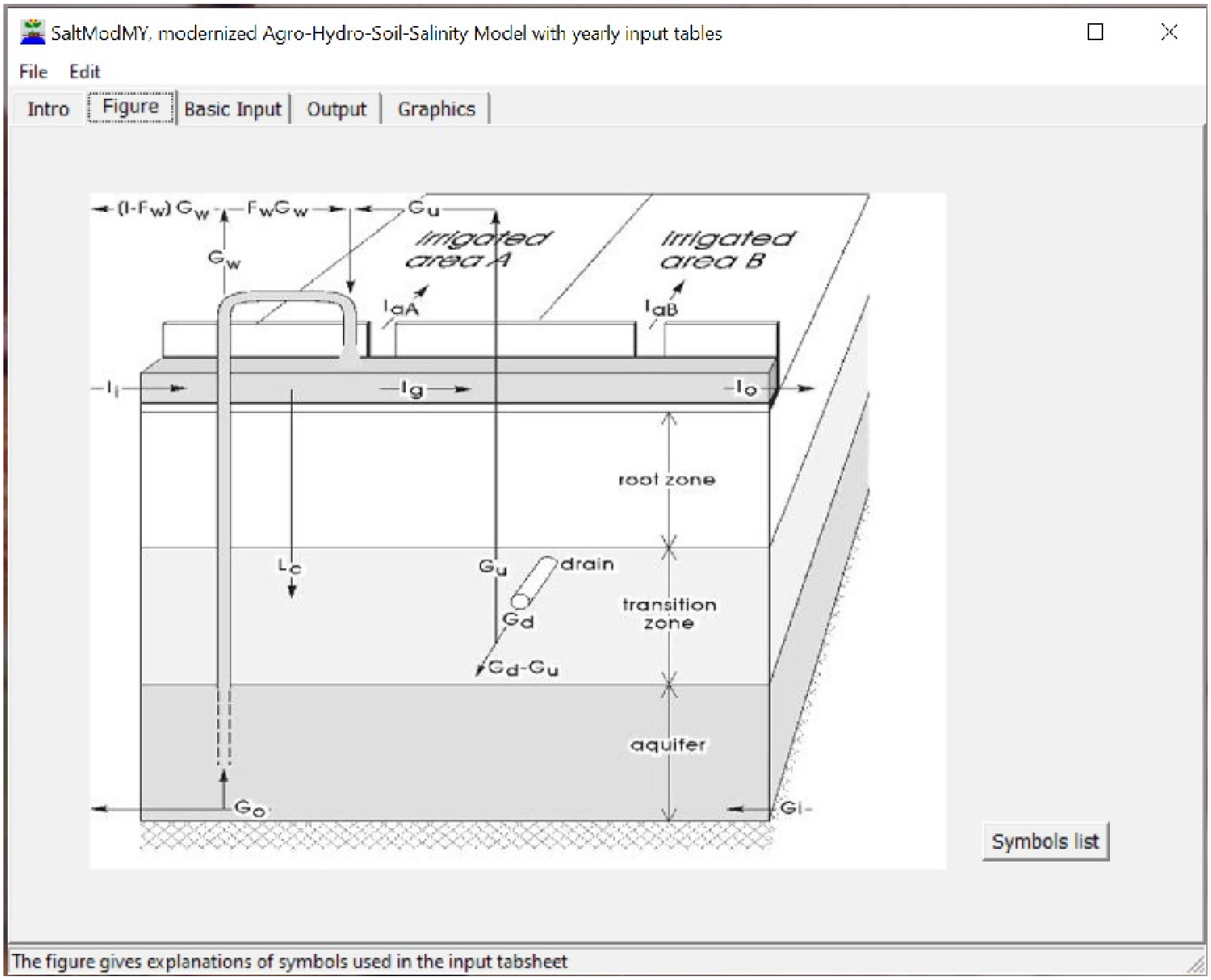


Figure 1. *Some of the hydrological factors considered in Saltmod and it concerns two neighboring area A and B with different irrigated crops while the soil is divided into three layers. The button "Symbols list" helps in finding the definitions of the symbols used.*

2. Differences between SaltMod and SaltModM

The equations used in SaltMod and SaltModM are the same and they can be consulted in *Reference 3.* The main difference rests with the input menu, see *Figures 2a, 2b, 2c, 2d and 3.*

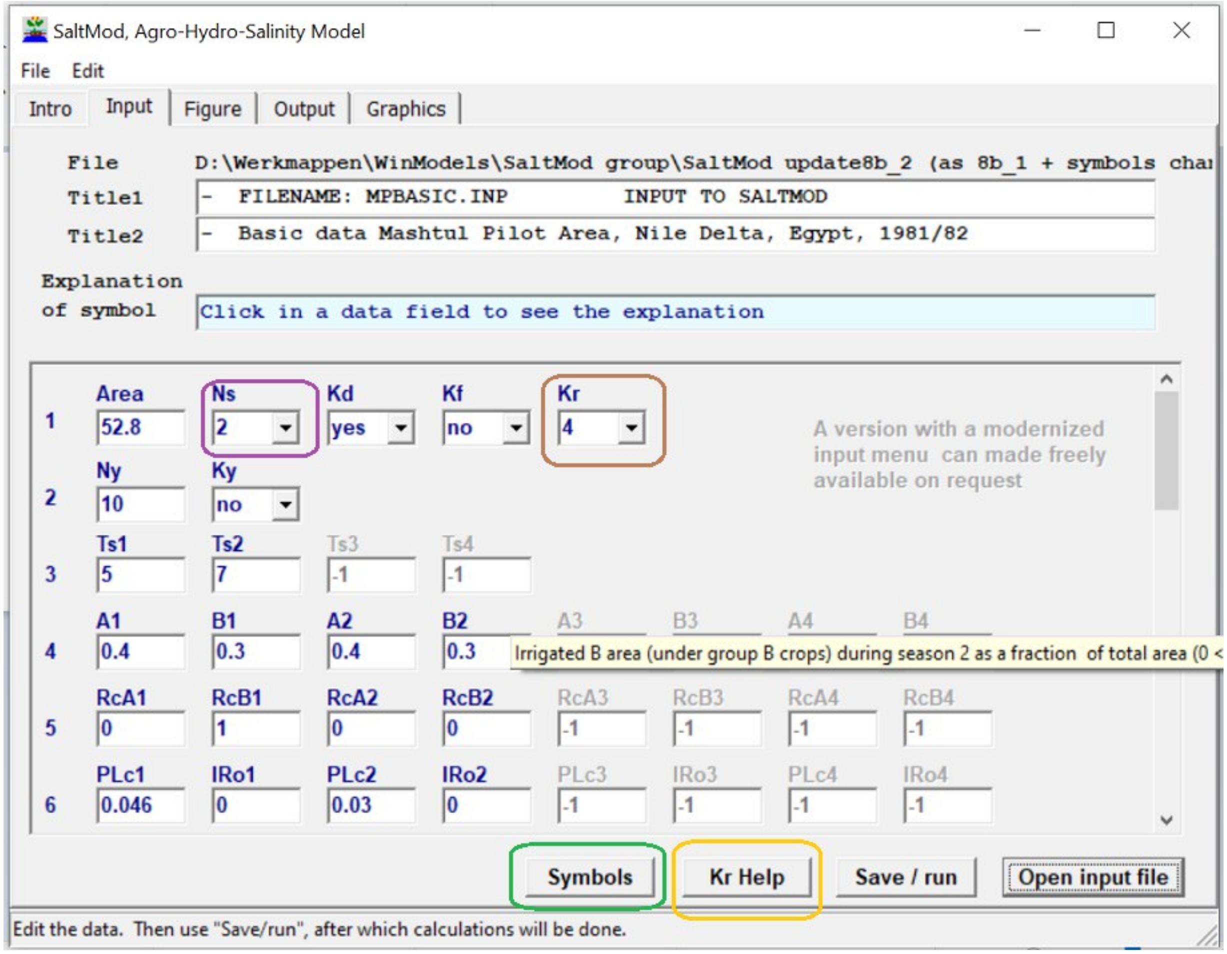
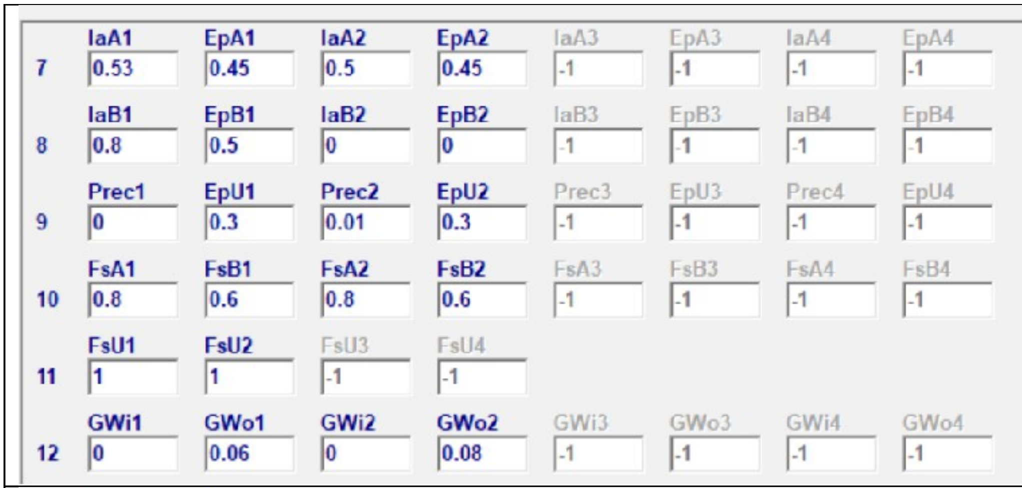


Figure 2a. *Top part of the SaltMod input menu. In the blue line we see a suggestion for an explanation of the symbols used. For example by clicking on the field B2 we see a hint in yellow color. Further the complete list of symbols van be found by clicking on the Symbols button (green square). The Kr symbol (top right, brown square), which stands for the type of crop rotation, is given an extra explanation (orange square). The group of input edits that has been disabled, standing for seasons 3 and 4 in a year, fall beyond the scope of the this data sheet, because the model id defined for only two seasons in a year (purple square).*

Figure 2a is continued on the next page.



Line								
	IaA1	EpA1	IaA2	EpA2	IaA3	EpA3	IaA4	EpA4
7	0.53	0.45	0.5	0.45	-1	-1	-1	-1
	IaB1	EpB1	IaB2	EpB2	IaB3	EpB3	IaB4	EpB4
8	0.8	0.5	0	0	-1	-1	-1	-1
	Prec1	EpU1	Prec2	EpU2	Prec3	EpU3	Prec4	EpU4
9	0	0.3	0.01	0.3	-1	-1	-1	-1
	FsA1	FsB1	FsA2	FsB2	FsA3	FsB3	FsA4	FsB4
10	0.8	0.6	0.8	0.6	-1	-1	-1	-1
	FsU1	FsU2	FsU3	FsU4				
11	1	1	-1	-1				
	GWi1	GWo1	GWi2	GWo2	GWi3	GWo3	GWi4	GWo4
12	0	0.06	0	0.08	-1	-1	-1	-1

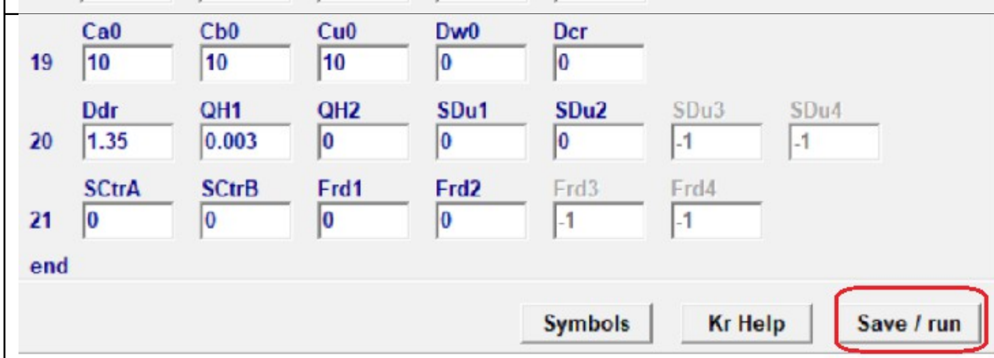
Figure 2b.

Second part of SaltMod input menu

Line								
	SiU1	SoU1	SiU2	SoU2	SiU3	SoU3	SiU4	SoU4
13	0	0	0	0	-1	-1	-1	-1
	SoA1	SoB1	SoA2	SoB2	SoA3	SoB3	SoA4	SoB4
14	0	0	0	0	-1	-1	-1	-1
	PGw1	FPw1	PGw2	FPw2	PGw3	FPw3	PGw4	FPw4
15	0	-1	0	-1	-1	-1	-1	-1
	Dro	PTro	Dtr	PTtr	Daq	PTaq		
16	0.6	0.5	6	0.5	50	0.6		
	PEro	FLro	PEtr	FLtr	PEaq	FLaq		
17	0.05	1	0.05	1	0.1	1		
	SCtr	SCaq	SCic	SCigw	SCrain			
18	0	0	0	0	0			

Figure 2c.

Third part of SaltMod input menu



Line							
	Ca0	Cb0	Cu0	Dw0	Dcr		
19	10	10	10	0	0		
	Ddr	QH1	QH2	SDu1	SDu2	SDu3	SDu4
20	1.35	0.003	0	0	0	-1	-1
	SCtrA	SCtrB	Frd1	Frd2	Frd3	Frd4	
21	0	0	0	0	-1	-1	
end							

Figure 2d.

Last part of SatMod input menu. In total there are 21 lines of data.

Use Save/run (red square) for the calculations.

Continuation of *Figure 2a*.

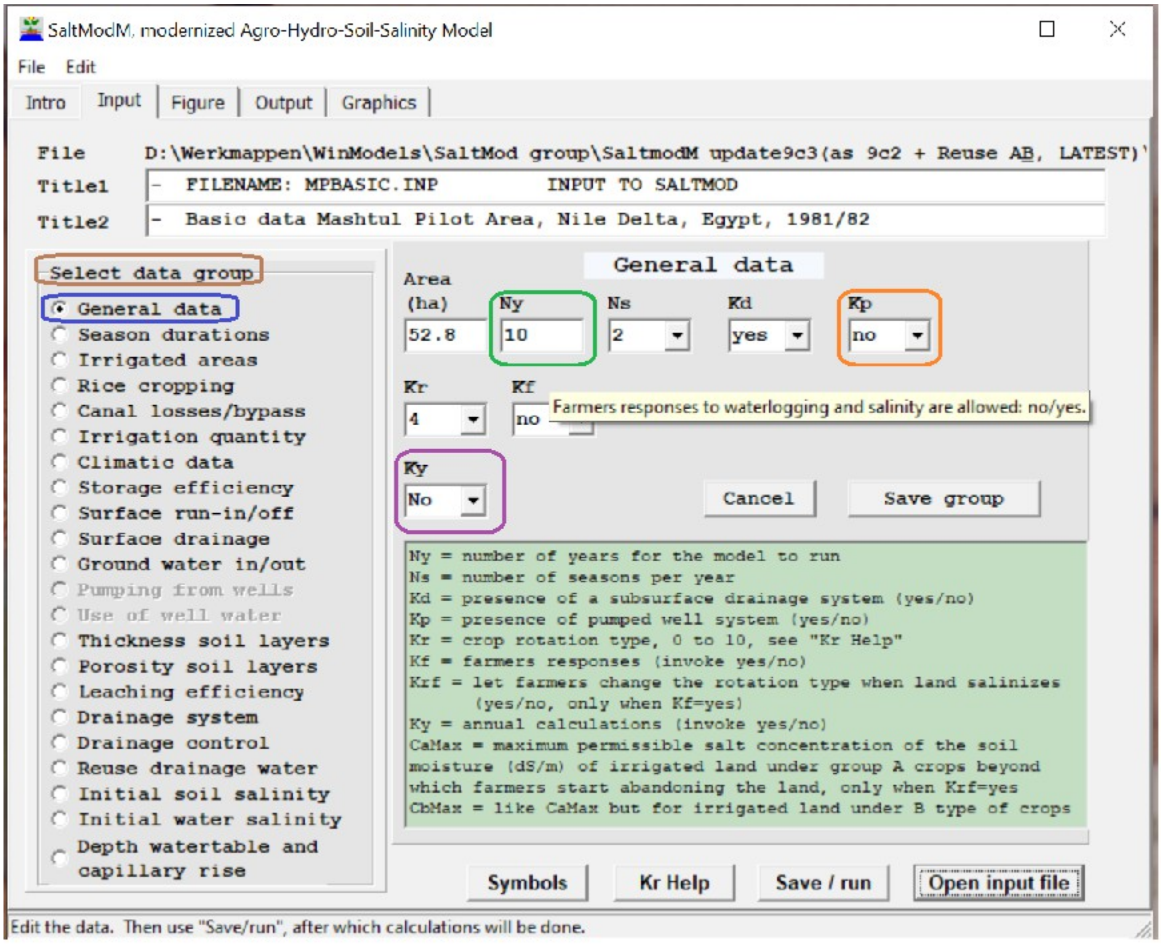


Figure 3. *Input menu of the modernized version of SaltMod's model called SaltModM. The input page is more compact. In this example the generalized data (blue square) are visible and can be edited. The relevant symbols are clarified in the green field. The yellow line is a cursor hint for the symbol Kf specifying the option to simulate the farmers' responses (Yes/No). The other data can be accessed using the various radio buttons in the select data group table (brown square). Two items in the list of selectable data groups are grayed out. They are not applicable because in the general data group the Kp option indicates that there is no pumped well system present (orange square). The operational buttons right under are the same as those in the classic model and clarified in* figures 2a and 2d.

It is a specialty of SaltModM to offer the user the choice of letting him run the program in one go for the total number of years specified (Ny, green square) or letting him pause the program after each year so that eventual input values (for example the rainfall) can be adjusted year by year. This choice can be accomplished by means of the Ky index (purple square).

Instead of pausing the program annually, it is also possible to enter all annual data per season in the input menu of the extended modernized SaltModM program called SaltModMY (*Figure 4*).

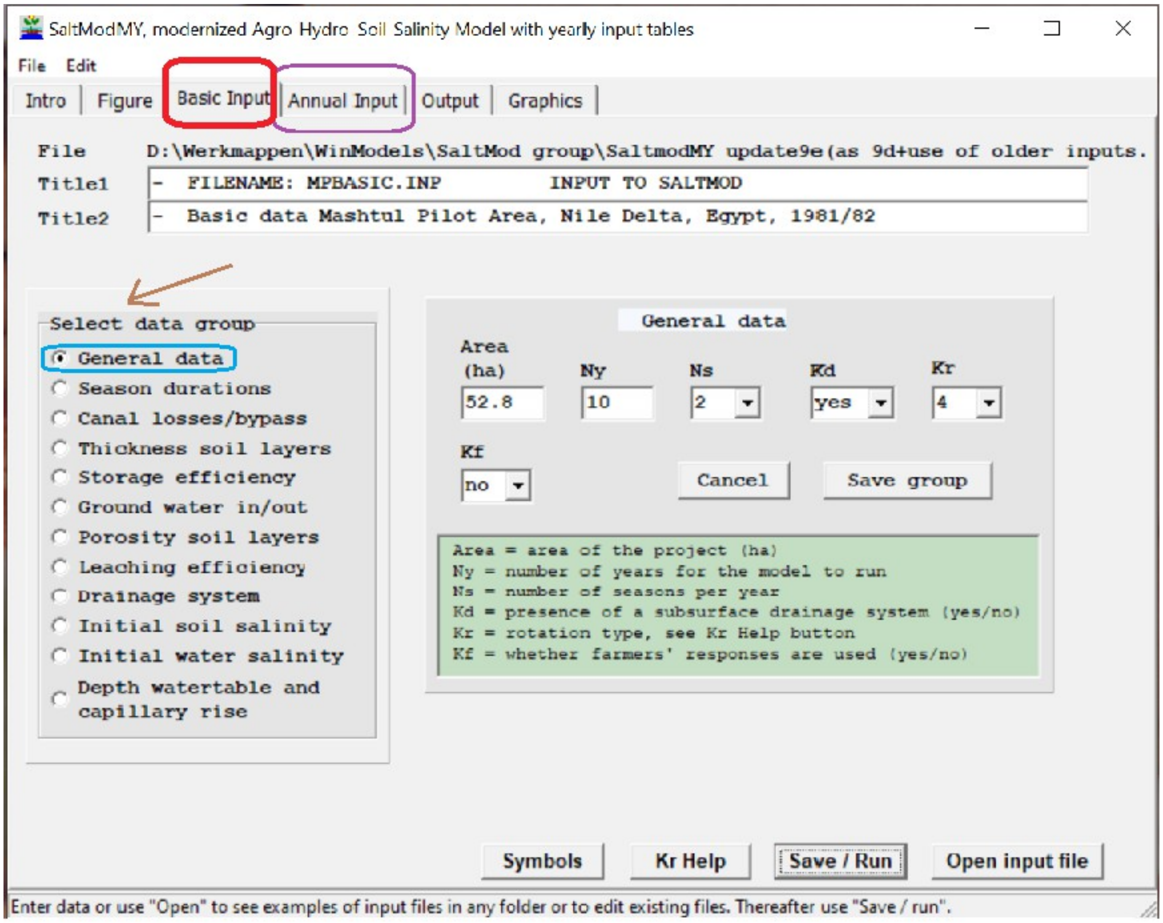


Figure 4. *The extended program SaltModMY allows the specification of annually varying seasonal input values. For that reason an extra tab sheet has been added (purple square). This results in a shorter list of basic inputs (red square) compared to the list in SaltModM (*Figure 3*).*

In *Figure 4*, the tab sheet that has been opened is that of the basics inputs. The tab sheet that can be opened for annually varying seasonal data is next to it (purple square). *Figure 5* shows a picture of what the tab sheet for annual data looks like.

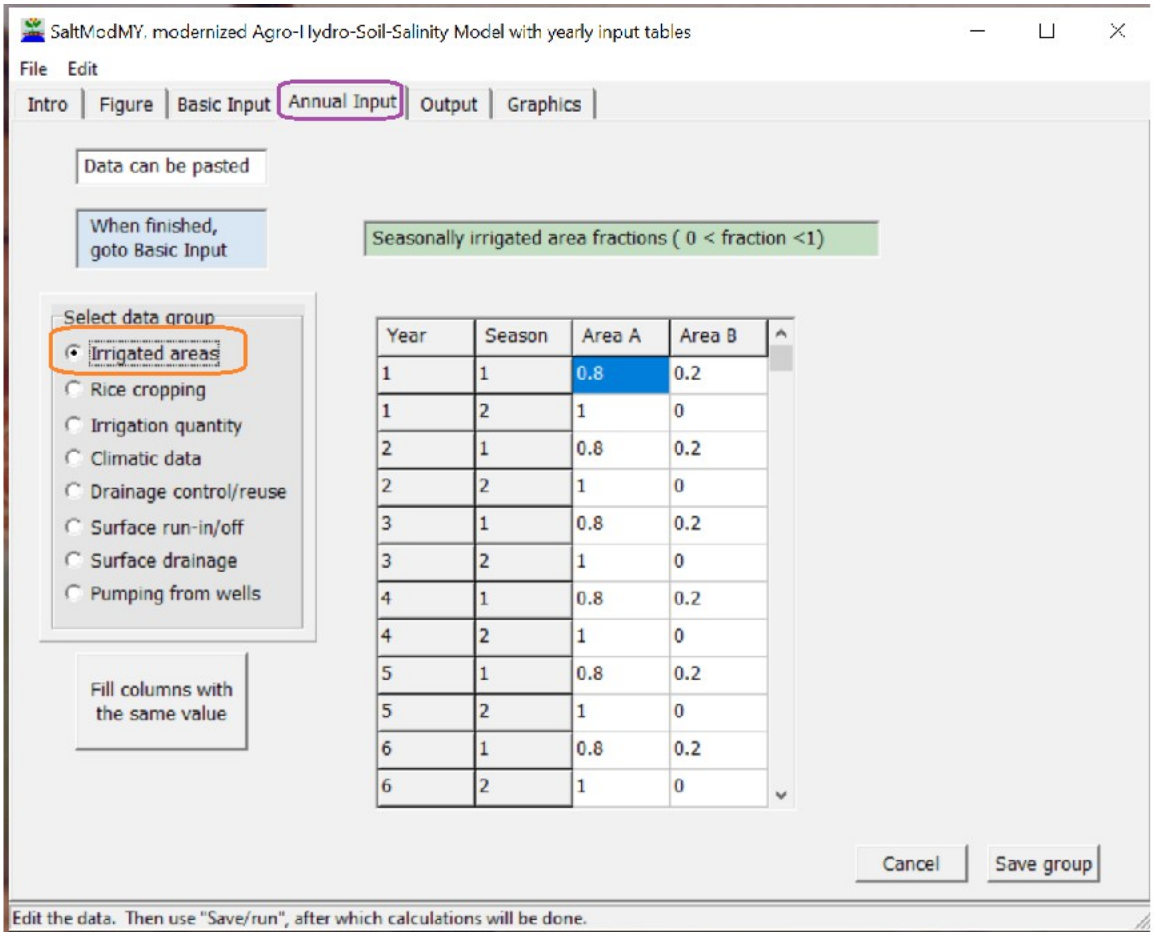


Figure 5. *The SaltModMY tab sheet for annually varying seasonal inputs (purple square) show a list of items from which the irrigated areas radio button (red square) has been selected. There are two areas (A and B) with different crops. In this example there is no annual variation, but it can be introduced.*

3. Illustration of results of SaltModM

The output menu of SaltMod gives the option to select output categories (groups) as demonstrated in the next figure.

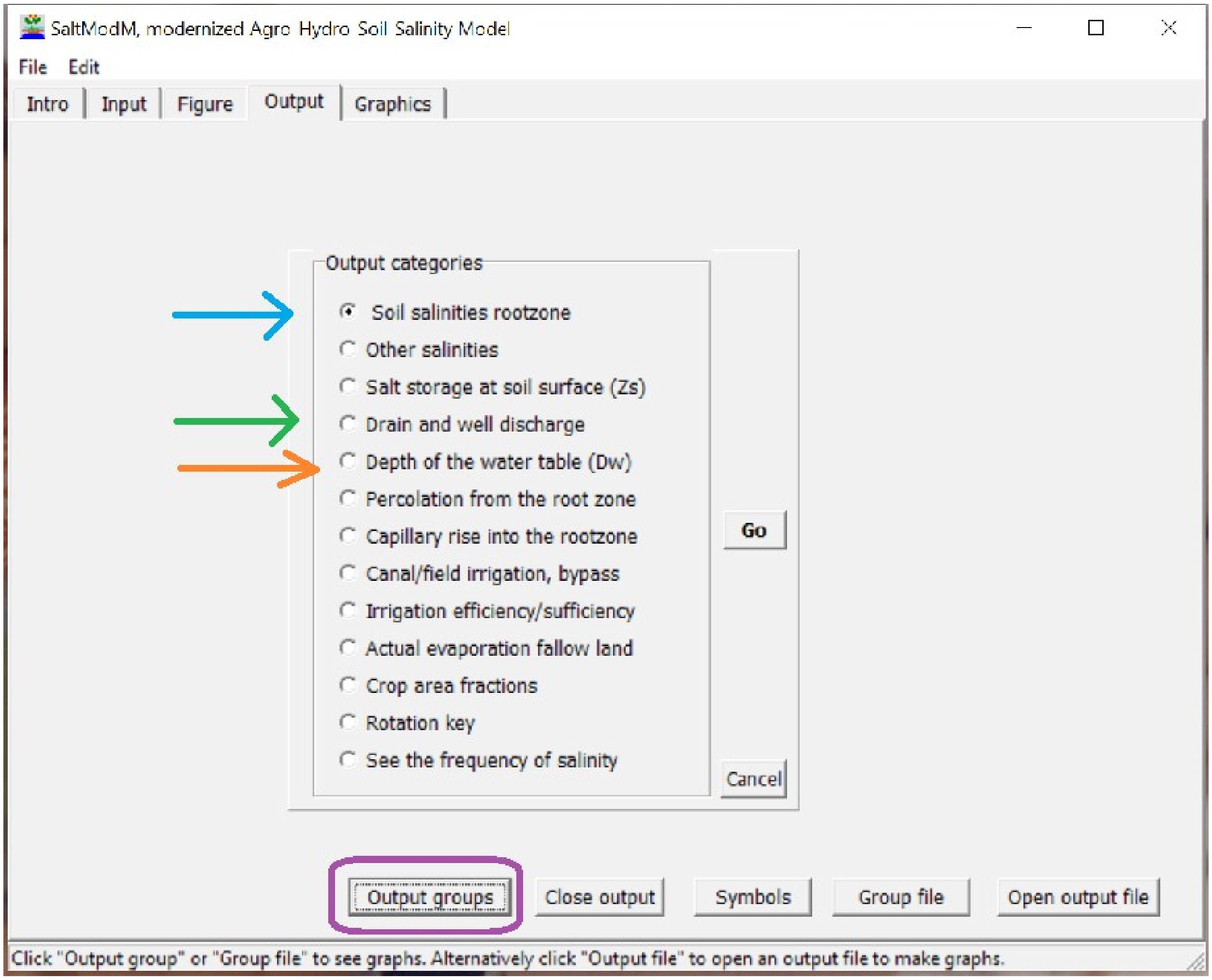


Figure 3A. *Output groups (categories, purple square) from which the root zone soil salinity (blue arrow), the drain discharge (green arrow) and the depth of the water table (orange arrow) will be selected in the following illustrations of the SaltModM applications to 3 pilot areas in India.*

3.1 Konanki pilot area

The Konanki pilot area is approximately 300 km east of Hyderabad and 80 km away from the coast h South India. The area is waterlogged with depth to water table varying from O to 3.74 m and had salinity and sodicity problems (1.3 <EC,< 30 dS/m; 7.2 < pH < 10.0; 14.1 < ESP < 54.6). A pipe drainage system was installed in an area of 8 ha in the central part of the pilot area in May 1999. On the northern side of the collector drain, ten pipe drains at a spacing of 30 m and on the southern side, five pipe drains at double spacing of 60 m were installed at a depth varying from 0.9 to 1.1 m below the ground surface. An open (deep) drainage system with three drains of 1 m depth at a spacing of 100 m was also constructed in the northern part of the pilot area. The topography of the pilot area permitted gravity outflow at the end of the open drains and collector drain to dispose off the collected drain water into the natural drain, which is flowing north at the eastern side of the pilot area. A

Apart from monitoring the performance of drainage systems in the pilot area, the salt and water balance studies were initiated in the pilot area in the year 2000. As a part of these studies, the quantity and quality of all the inflows and outflows are being measured at regular intervals. The canal water entering the pilot area is being measured with Parshall flumes installed at the three inlet points. In the pilot area, groundwater is not used for irrigation and hence it was not considered in the study. A standard rain gauge and a Class A pan were installed.

Evapotranspiration is being estimated using the pan evaporation data and crop coefficients. Other meteorological data are collected from the nearby Indian Meteorological Department (IMD) observatory. Discharges from individual lateral pipe drains and outlets of drainage systems are being measured regularly. The depth to groundwater table in the observation wells as well as battery of piezometers is also being measured regularly. The data related to water quality are being collected at fortnightly intervals. Soil salinity is being measured in May every year in 3 layers, viz. 0-20 cm, 21-50 cm and 51-100 cm at 58 grid locations uniformly spread over the pilot area.

Using the raw data collected at the Konanki pilot area, most of the parameters are estimated for use in SALTMOD input file (Tables 16 and 17 as copied in *Appendix 6a*). Values of few of the parameters are assumed logically. Some of the parameters, notably the natural drainage of groundwater through the aquifer and the leaching efficiencies of the root zone and transition zone could not be measured. Before applying SALTMOD, these factors were determined by running trials with SALTMOD using different values of leaching efficiency and natural drainage. Values were selected that produced soil salinity and depths to water table that matched well with the actually measured values.

Graphs of the output variables soil salinity of the root zone, depth of the groundwater table, and drain discharge are depicted in the next figures. The model is made with 3 seasons of 3, 4 and 5 moths respectively. In the first season green manuring is done on the rainfall without irrigation, in the second season rice (paddy) is grown under irrigation, while in the last season the land was left fallow.

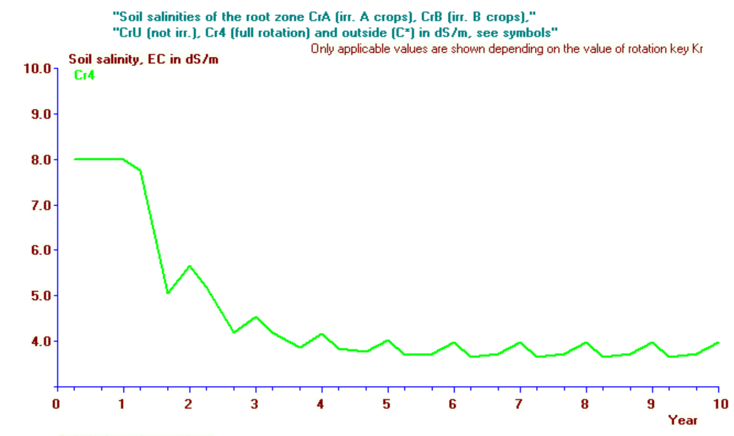


Figure 3a.1

The initial value of the root zone soil salinity (Cr4, ECe = 8 dS/m) indicates a salinized soil.

After for years of reclamation with the help of a drainage system, the salinity dropped to below 4 dS/m, which is a safe value.
The upward trend is season 3 is due to capillary rise, see figure 3a.2

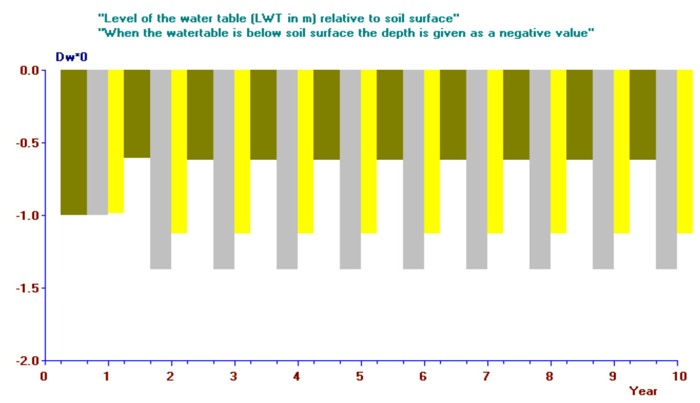


Figure 3a.2

The dept of the during the reclamation period has seasonal fluctuations. The water table is shallow (0.5 m, olive green color) in season 2, when rice cultivation occurs, and deep in season 3 (1.4 m, gray color), which is a fallow period. As the drains are at 1 m depth, the gray depth is below drain depth, mainly due to capillary rise as the root zone becomes dry and sucks the groundwater up.

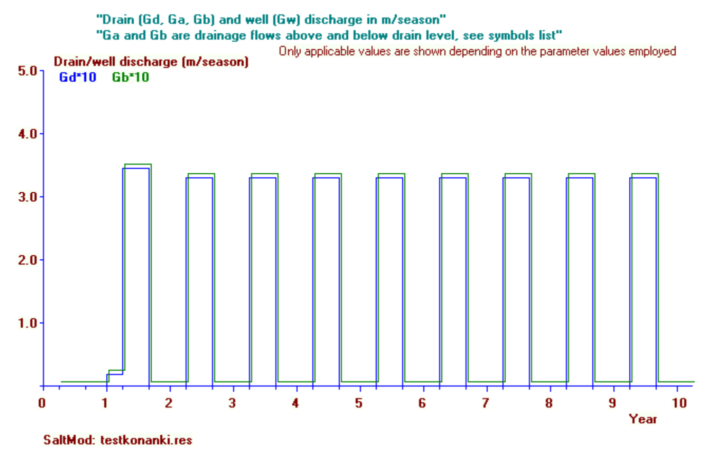


Figure 3a.3

*The drain discharge (Gd*10, dm/season) is highest in season 2 (Gd = 3.4 dm /season) when a rice crop is grown. Beyond that the discharge is zero as the water table drops below drain level, see figure 3a.2*

Figure 3a. *A selection of the output results of SaltMod used in the* Konanki *pilot area.*

The leaching efficiency of the root zone has been calibrated, see Figure 3a.4.

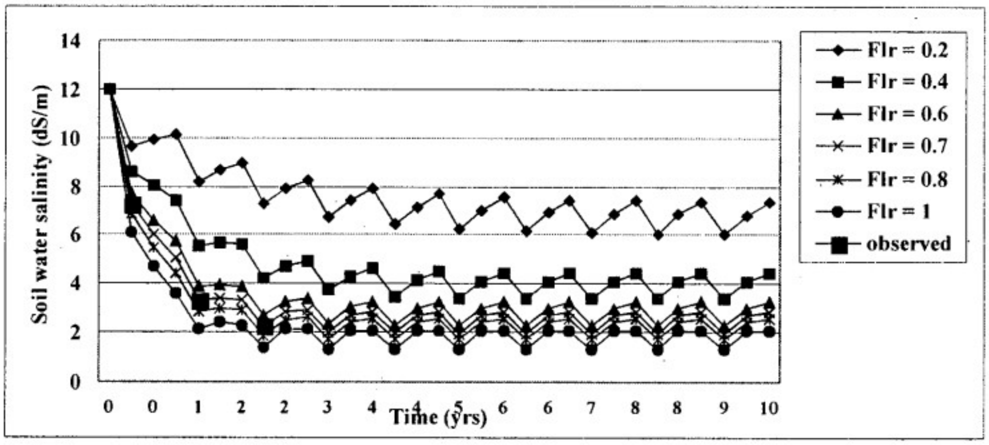


Figure 3a.4 *Calibration of the leaching efficiency Flr of the root zone (copied from* Reference 1*)*

Comparing the assumed Flr values with the observed ones the conclusion can be drawn that the actual Flr value is close to 0.9, meaning that the salt concentration of the downward percolation water is 90% of that of soil moisture in the root zone. The percolation water flows mainly through the larger soil pores so that the salts in the smaller pores are not washed out.

3.2 Segwa pilot area. Kakrapur irrigation command, South Gujarat, India

A 188 ha block in Segwa minor of Surat branch in Kakrapar irrigation command was selected for operational research on drainage and related water management. The area is bounded in the North by Surat branch, a natural drain in South, Segwa minor in the west and a cart road in the East. This area is about 10 km inside towards East of Bombay-Ahmedabad road (National highway No. 8). About one third of the area on the eastern side of this road is irrigated by tube wells while the remaining part is irrigated through canal water. Conjunctive use of water is also made in some parts of the canal command. Waterlogging coupled with initiation of secondary salinisation is deteriorating the soil health and crop productivity in the pilot area.

The data used in SALTMOD are collected before and after the installation of drainage system. The model was calibrated by using the data on cropping pattern, water table, hydraulic conductivity, salinity status, leaching efficiencies, drain discharges etc. The input parameters used in calibrating the model are shown in Tables 21 and 22 in *Appendix 6b*.

Graphs of the output variables soil salinity of the root zone, depth of the groundwater table, and drain discharge are depicted in the next figures. The model is made with 3 seasons of 5, 4 and 3 months respectively. In the first season green sugarcane and rice (paddy) are cultivated, in the second season only sugarcane is grown under irrigation, while in the last season the land was is used again by both sugarcane and rice. However 25% of the land is left barren (fallow).

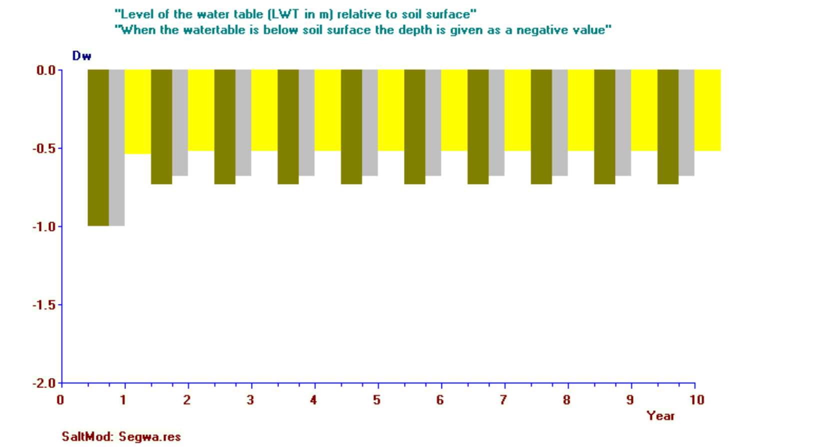


Figure 3b.1

The dept of the water table (Dw) during the reclamation period has seasonal fluctuations. The water table is shallow (0.5 m, yellow color) in season 1, when rice cultivation occurs, and only slightly deeper inn deep in season 2 and 3 (0.7 m, olive green and gray color).area is used intensively in all 3 seasons and the are no dry periods to get the water table down to 1 m.

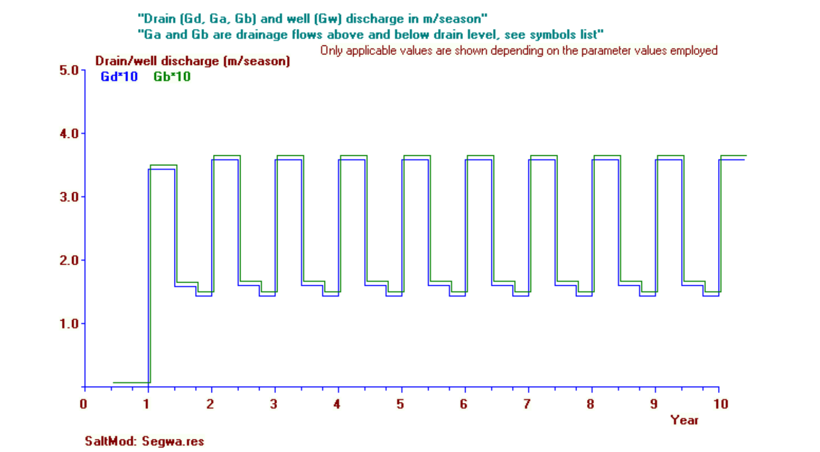


Figure 3b.2

Owing to the intensive land use throughout the year with the help of rain and irrigation water, the drainage system keeps working all the time. The highest discharge occurs in season 1, when sugarcane in its early development, which requires much water, combined with paddy (rice grown under water) produce the largest downward percolation of water.

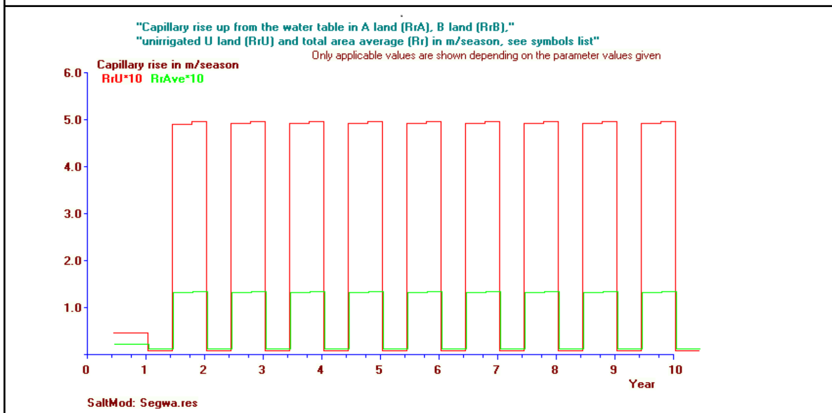


Figure 3b.3

In the 25% fallow land(U land), where irrigation is absent, the soil becomes dry and sucks up a large amount of groundwater by capillary rise (RrU, red color), the more so since the water table is shallow (see Figure 3b.1).

The average capillary rise over the whole areas much less (Rave, green color);

Figure 3b. *A selection of the output results of SaltMod used in the* Segwa *pilot area.*

3.3 Tungabhadra pilot area

The Tungabhadra irrigation project is a major inter-state irrigation project of peninsular India. It was commissioned during 1953 with an irrigation potential of 3.63 lakh hectares in Karnataka and 1.6 lakh hectares in Andhra Pradesh. The project was designed for protective irrigation and almost three-fourth of the command area was earmarked for light irrigated crops.

The topography of the Left Bank Command area is rather undulating and only occasionally gives the impression of a flat plain. The canal is a contour canal and forms the boundary of the command areas of two adjacent distributaries. Field experiments on an interceptor drainage system were conducted during 1998-2001 at distributary D-36/1, covering an area of 62 ha. This distributary runs on a well-defined ridge perpendicular to the main canal. A three-tier interceptor drain of 10 cm diameter was laid at a depth of 0.75 m from the surface to intercept the incoming seepage flows from canal and prevent waterlogging and soil salinisation in low lying areas. The drains were laid at a spacing of 150 m running parallel to D-36/1 near Sindhanur during 1998. The drain placement is about 100 m away from the natural drain (Vade halla) and 1500 m from the canal. The interceptor drains are laid with corrugated and perforated PVC pipes with filters.

Performance of interceptor drainage system was evaluated in terms of changes in soil salinity, depth to water table, crop yield, cropping intensity, etc. The study was initiated during kharif 1998 and continued up to kharif 2001. Changes in soil salinity due to interceptor drainage system were evaluated by collecting soil samples at 12 grids points. The performance of interceptor drainage system was also monitored in terms of changes in depth to water table. Water table depth was recorded in each crop season after the harvest of the crop. To assess the amount of salts removed from the study area, drain discharge was measured periodically and analysed for its quality. To study the individual performance of the three parallel interceptor drains, individual drain discharge and its salinity was measured separately during Aug. 2000 to May 2001. These three drains removed almost same quantity of drainage water and their salt concentration is also more or less similar. It indicates that the drainage water removed through the drains is mostly from the paddy area than intercepted seepage from the canal.

The model uses 4 seasons of 5, 1, 4 and 2 months. During the 1st season under water rice (paddy) is grown, in the 2nd season the land is left fallow, During the 3rd season again paddy is cultivated, while in the last season the land is left fallow again. The input parameters used in the model are shown in Tables 21 and 22 in *Appendix 6c*.

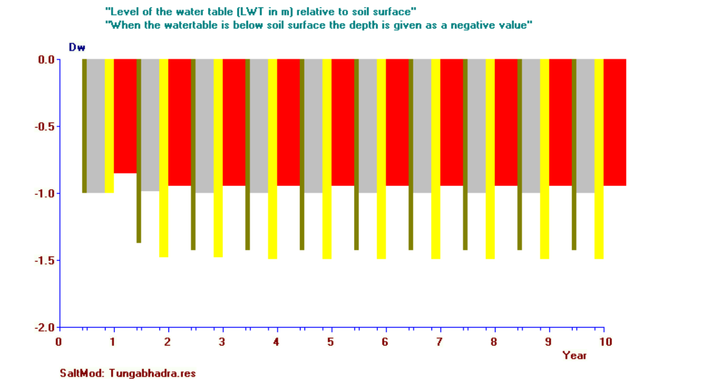


Figure 3c.1

The dept of the water table (Dw) has seasonal fluctuations. The water table is shallow (0.5 m, yellow color) in season 1 (red color) and season 3 (black), when rice cultivation occurs. In the fallow periods (black and yellow) Dw is considerably deeper and it goes down to practically 1.5 m

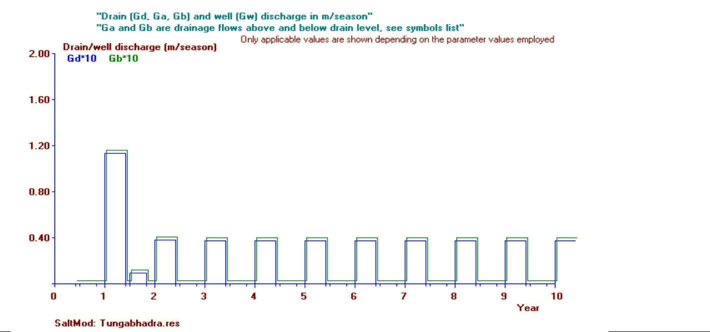


Figure 3c.2

The drain discharge (Gd) is restricted mainly to season 1 when irrigation water is applied complemented with rain, while in season, although there is irrigation, the discharge is small owing to the absence of rainfall.

Figure 3bc *A selection of the output results of SaltMod used in the* Tungabhadra *pilot area.*

4. Conclusions

SaltMod is a very useful model for prediction of salinity of soil moisture, groundwater and drainage water, the depth of the water table and the drain discharge in irrigated agricultural land under varying water management options. Its simplicity of operation and minimum requirement of field data promotes its use by field engineers to obtain results that could be useful for planners (Reference 1).

The model SaltMod for the Segwa minor canal command, once it was calibrated and validated with the data collected in the Segwa pilot area, predicted fairly correct trends for both the water table and soil salinity. Canal command areas are likely to get salinised if appropriate drainage intervention is not introduced. SaltMod is an effective tool to forecast water table and soil salinity under various situations and therefore, could help in the design of drainage systems once the basic input parameters are known (Reference 1).

As an important conclusion, in the report "*Research on the control of water logging and salinization in irrigated agricultural lands" (Reference 1)* is that several scenarios were developed to test a number of alternatives for the drainage system and the irrigation regime considering different designs while securing a safe control of the soil salinity and the level of the groundwater table, while assessing a possible reduction of irrigation applications.

For Konanki, one of the scenarios concerns the consequences of using different subsurface drainage systems, to check if cheaper systems with a wider drain spacing is allowable, or whether a more expensive system with greater intensity would be recommendable.

Figure 3a.5 illustrates the depth of the water table under the present drainage system with capacity factor QH1 = 0.005 (m^2/day), with a halved capacity factor QH1 = 0.0025 representing a cheaper system with wider drain spacing, and with a doubled capacity factor (QH1 = 0.01) which stands for a more expensive drainage system with narrower drain spacing.

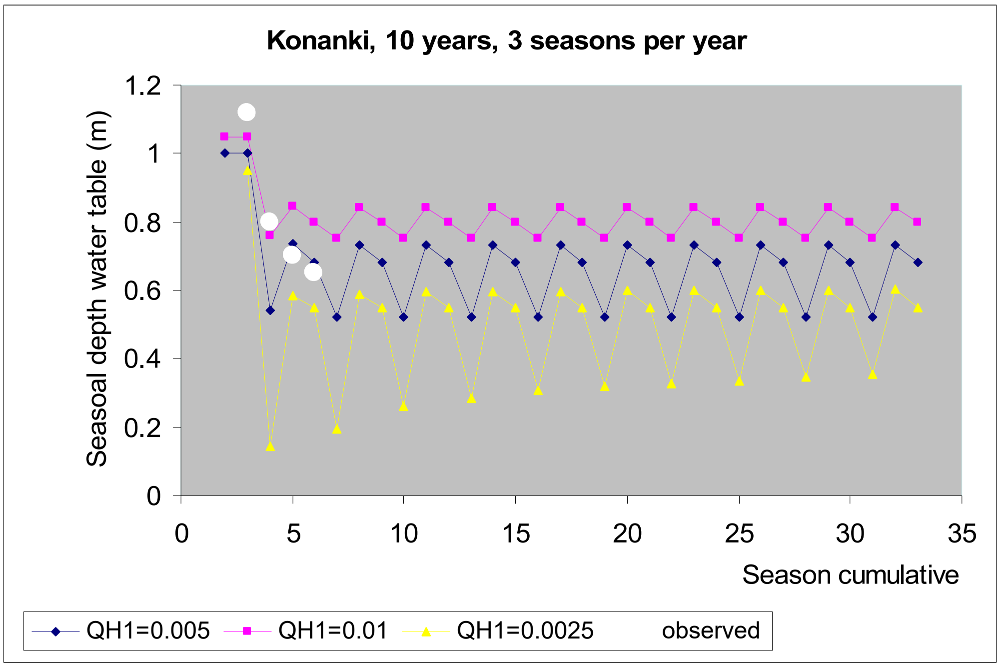


Figure 3a.5. *When the drainage capacity QH1 = 0.005 m^2/day, corresponding to the actual subsurface drainage system (blue color), the depth of the water table tends to reach an equilibrium value of 0.6 m, which is usually acceptable. At a higher capacity QH1 = 0.01 (rose color), the depth of the water table gets deeper and achieves an average value of 0.75 m. At a lower capacity QH1 = 0.0025, the depth becomes shallower at an average of 0.4 m, which under most condition is not enough as the water table enter the root zone.*

SaltModM offers the possibility to calculate the drainage capacity factor QH1 (and also a second factor QH2 accounting for the drainage flow above drain level) form the parameters of a subsurface drainage system as explained in *Appendix 6d*,

5. References

Reference 1.
Research on the control of water logging and salinization in irrigated agricultural lands. Computer Modeling in Irrigation and Drainage. Conference paper published in 2002 in India by Central Soil Salinity Research Institute, Karnal (India) and Alterra- International Institute for Land Reclamation and Improvement, Wageningen (The Netherlands)
On line: https://edepot.wur.nl/25913https://edepot.wur.nl/25913
or:
https://www.researchgate.net/publication/40794959_Research_on_the_control_of_waterlogging_and_salinization_in_irrigated_agricultural_lands_recommendations_on_waterlogging_and_salinity_control_based_on_pilot_area_drainage_research

Reference 2.
List of publications in which SaltMod is used. On line:
https://www.waterlog.info/pdf/SaltModlist.rtf

Reference 3.
SaltMod. Description of Principles, User Manual, and Examples of Application. On website
https://www.waterlog.info/pdf/saltmod.pdf

6. Appendices

The data presented in the following sections were obtained as copies from pages in the project report (Reference 1).

Appendix 6a. Konanki pilot area, Nagarjuna Sagar project, Andra Pradesh

The Konanki pilot area is approximately 300 km east of Hyderabad and 80 km away from the coast of South India. The area is waterlogged with depth to water table varying from O to 3.74 m and had salinity and sodicity problems (1.3 <EC,< 30 dS/m; 7.2 < pH < 10.0; 14.1 < ESP < 54.6). A pipe drainage system was installed in an area of 8 ha in the central part of the pilot area in May 1999 (Fig. 8). On the northern side of the collector drain, ten pipe drains at a spacing of 30 m and on the southern side, five pipe drains at double spacing of 60 m were installed at a depth varying from 0.9 to 1.1 m below the ground surface. An open (deep) drainage system with three drains of 1 m depth at a spacing of 100 m was also constructed in the northern part of the pilot area. The topography of the pilot area permitted gravity outflow at the end of the open drains and collector drain to dispose off the collected drain water into the natural drain, which is flowing north at the eastern side of the pilot area.

Apart from monitoring the performance of drainage systems in the pilot area, the salt and water balance studies were initiated in the pilot area in the year 2000. As a part of these studies, the quantity and quality of all the inflows and outflows are being measured at regular intervals. The canal water entering the pilot area is being measured with Parshall flumes installed at the three inlet points (Fig. 8). In the pilot area, groundwater is not used for irrigation and hence it was not considered in the study. A standard rain gauge and a Class A pan were installed. Evapotranspiration is being estimated using the pan evaporation data and crop coefficients. Other meteorological data are collected from the nearby Indian Meteorological Department (IMD) observatory. Discharges from individual lateral pipe drains and outlets of drainage systems are being measured regularly. The depth to groundwater table in the observation wells as well as battery of piezometers is also being measured regularly. The data related to water quality are being collected at fortnightly intervals. Soil salinity is being measured in May every year in 3 layers, viz. 0-20 cm, 21-50 cm and 51-100 cm at 58 grid locations uniformly spread over the pilot area.

Table 16. Season-wise input parameters for use with SALTMOD

Serial No.	Parameters	Season 1	Season 2	Season 3
1	Duration	13 July to10 October (3 months)	11 October to12 March (5 months)	13 March to12 July (4 months)
2	Crops grown	Green manuring (crops like sun hemp)	Paddy	Fallow
3	Source of water	Rainfall No irrigation water	Rainfall and Canal water	Rainfall No irrigation water
4	Fraction of area occupied by irrigated crop	-	1.0	-
5	Fraction of area with unirrigated crops	1.0	-	-
6	Fallow	-	-	1.0
7	Rainfall (m)	0.472	0.250	0.180
8	Canal water used for irrigation (m)	-	0.625	-
9	Groundwater used for irrigation	-	-	-
10	Potential evapotranspiration of crops /non-irrigated area (m)	0.354	0.539	0.718
11	Percolation from canal system (m)	-	0.10	-
12	Outgoing surface runoff (m)	0.06	0.10	-

Table 17. Other input parameters for use with SALTMOD

Serial No.	Parameter	Value
1	Storage efficiency	0.75
2	Depth of root zone	0.40
3	Depth of transition zone	1.60
4	Depth of aquifer	7.0
5	Total pore space of root zone	0.40
6	Total pore space of transition zone	0.60
7	Total pore space of aquifer	0.40
8	Effective porosity of root zone	0.045
9	Effective porosity of transition zone	0.045
10	Effective porosity of aquifer	0.10
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	-Root zone	11.52
	-Transition zone	12.10
	-Aquifer	3.05
12	Salt concentration of canal water (dS/m)	0.60
13	Initial depth to water table from ground surface	1.65
14	Critical depth of water table for capillary rise	1.50

On the basis of preliminary calibration and application of SALTMOD for salt and water balance modelling of the Konanki pilot area, the following conclusions have been drawn: SALTMOD is a very useful tool for prediction of salinity of soil water, groundwater and drainage water, the depth of the water table and the drain discharge in irrigated agricultural land under varying water management options. Its simplicity of operation and minimal requirement of data that are generally available should help in promoting its use by the engineers to obtain the results that could be useful for the planners. From calibration of the model, the leaching efficiencies of root zone and transition zone in the pilot area are estimated to be 65%. There is a natural outflow of 50 mm of groundwater every year from the pilot area into the natural drain. The model predicts that due to the existence of drainage system, the root zone soil water salinity will be reduced to 4,3 and 2.5 dS/m (from an initial value of 11.5 dS/m) during the first, second and third seasons within six years. Closer. than the present spacing will not be of any advantage. The requirement of irrigation water could be reduced to about 80% of its present value without any detrimental effect on root zone soil salinity. This would also alleviate the problems of waterlogging and salinity to some extent. .

Appendix 6b. Data Segwa pilot area, Ukai-Kakrapar, South Gujarat

Ukai-Kakrapar is a major irrigation project in South Gujarat. This is the biggest multi-purpose project built on the river Tapi. The Kakrapar weir was constructed as stage I and regular irrigation in its command commenced in 1957. The Ukai dam was constructed as stage I1 and regular irrigation and construction of Ukai canal distributary system was started in 1974 and completed by 1983. The total cultivable command area of the project is 3.31 lakh ha distributed in Surat (1.9 lakh ha), Valsad (0.96 lakh ha) and Bharuch (0.45 lahk ha) districts.

A 188 ha block (Fig. 15) in Segwa minor of Surat branch in Kakrapar irrigation command was selected for operational research on drainage and related water management. It is located in between 73” 2’ 51” to 73” 3‘ 25” E longitudes and 21” 12’ 18” to 21” 13’ 31” N latitudes. The site encompasses four villages namely Segwa, Sevni, Asta and Vansda Rundhi in the Kamrej taluka of the Surat district at the Segwa minor ex. Surat branch of Kakrapar Left Bank Main Canal. The area is bounded in the North by Surat branch, Natural drain in South, Segwa minor in the west and a cart road in the East. This area is about 10 km inside towards East of Bombay-Ahmedabad road (National highway No. 8). A metalled road-joining village Segwa and Vansda Rundhi is bifurcating the area towards the East and the West. About one third of the area on the eastern side of this road is irrigated by tube wells while remaining is irrigated through canal water. Conjunctive use of water is also made in some parts of the canal command. Waterlogging coupled with initiation of secondary salinisation is deteriorating the soil health and crop productivity in the pilot area.

Table 21. Season-wise input parameter for use in SALTMOD

S.No.	Parameters	Season 1	Season 2	Season 3
1	Duration	15th Jun to 15th Nov (5 months)	16th Nov to 15th Mar (4 months)	16th Mar to 15th Jun (3 months)
2	Crops grown	Sugarcane, Paddy	Sugarcane	Sugarcane, Paddy
3	Water sources	Canal, Well	Canal, Well, Drain	Canal, Well, Drain
4	Fraction of area occupied by irrigated crop other than rice	0.60	0.75	0.60
5	Fraction of area occupied by irrigated rice crop	0.15	0.00	0.15
6	Fallow /barren	0.25	0.25	0.25
7	Rainfall (m)	0.90	0.02	0.10
8	Water used for irrigation in crops other than rice (m)	0.30	1.00	0.80
9	Water used for irrigation in rice crop (m)	0.65	0.00	1.40
10	Potential evapotranspiration of crops other than rice (m)	0.80	0.50	0.50
11	Potential evapotranspiration of rice crop (m)	1.35	0.00	0.90
12	Potential evapotranspiration from unirrigated area (m)	0.80	0.70	0.75
13	Outgoing surface runoff (m)	0.28	-	-

Table 22. Other input parameter for use in SALTMOD

S.No	Parameter	Value
1	Storage efficiency	0.75
2	Depth of root zone	0.85
3	Depth of transition zone	6.0
4	Depth of aquifer	50
5	Total pore space of root zone	0.50
6	Total pore space of transition zone	0.50
7	Total pore space of aquifer	0.60
8	Effective porosity of root zone	0.05
9	Effective porosity of transition zone	0.05
10	Effective porosity of the aquifer	0.20
11	Initial salt content of the soil moisture (dS/m) at field saturation in	
	-Root zone	12.0
	-Transition zone	7.0
	-Aquifer	-
12	Mean salt concentration of irrigation water in the pilot area (dS/m)	0.9
13	Initial depth of water table from ground surface	1.0
14	Critical depth of water table for capillary rise	1.6

The model SALTMOD for the Segwa minor canal command, once it was calibrated and validated with the data collected in the Segwa pilot area, predicted fairly correct trends for both the water table and soil salinity. Canal command areas are likely to get salinised if appropriate drainage intervention is not introduced. SALTMOD is an effective tool to forecast water table and soil salinity under various situations and therefore, could help in the design of drainage systems once the basic input parameters are known.

Appendix 6c. Data Tungabhadra pilot project, Karnataka, South-East Andra Pradesh

The Tungabhadra irrigation project is a major inter-state irrigation project of peninsular India. It was commissioned during 1953 with an irrigation potential of 3.63 lakh hectares in Karnataka and 1.6 lakh hectares in Andhra Pradesh. The project was designed for protective irrigation and almost three-fourth of the command area was earmarked for light irrigated crops.

The topography of the Left Bank Command area is rather undulating and only occasionally gives the impression of a flat plain. The canal is a contour canal and forms the boundary of the command areas of two adjacent distributaries. Field experiments on an interceptor drainage system were conducted during 1998-2001 at distributary D-36/1, covering an area of 62 ha. This distributary runs on a well-defined ridge perpendicular to the main canal. A three-tier interceptor drain of 10 cm diameter was laid at a depth of 0.75 m from the surface to intercept the incoming seepage flows from canal and prevent waterlogging and soil salinisation in low lying areas. The drains were laid at a spacing of 150 m running parallel to D-36/1 near Sindhanur during 1998. The drain placement is about 100 m away from the natural drain (Vade halla) and 1500 m from the canal. The interceptor drains are laid with corrugated and perforated PVC pipes with filters.

Performance of interceptor drainage system was evaluated in terms of changes in soil salinity, depth to water table, crop yield, cropping intensity, etc. The study was initiated during kharif 1998 and continued up to kharif 2001. Changes in soil salinity due to interceptor drainage system were evaluated by collecting soil samples at 12 grids points. The performance of interceptor drainage system was also monitored in terms of changes in depth to water table. Water table depth was recorded in each crop season after the harvest of the crop. To assess the amount of salts removed from the study area, drain discharge was measured periodically and analysed for its quality. To study the individual performance of the three parallel interceptor drains, individual drain discharge and its salinity was measured separately during Aug. 2000 to May 2001. These three drains removed almost same quantity of drainage water and their salt concentration is also more or less similar. It indicates that the drainage water removed through the drains is mostly from the paddy area than intercepted seepage from the canal.

Table 24. Season-wise input parameters for use with SALTMOD

Sl. No.	Parameters	Season 1	Season 2	Season 3	Season 4
1	Duration	1 August to 31 December (5 months)	1 January to 31 January (1 months)	1 February to 31 May (4 months)	1 June to 31 July (2 months)
2	Crops grown	Paddy	Fallow	Paddy	Fallow
3	Source of water	Rainfall and Irrigation water	Canal water	Irrigation water	Nil
4	Fraction of area occupied by irrigated crops	0.95	-	0.95	-
5	Fraction of area with unirrigated crops	-	-	-	-
6	Fallow	0.05	1.0	0.05	1.0
7	Rainfall (m)	0.55	0.0	0.05	0.0
8	Canal water used for irrigation (m)	0.55	0.0	1.05	-
9	Groundwater used for irrigation	Nil	Nil	Nil	Nil
10	Potential evapotranspiration of crops (m)	0.72	0.075	0.73	0.34
11	Percolation from canal system (m)	0.1	0.0	0.1	0.0
12	Outgoing surface runoff (m)	0.122	0.0	0.240	0.0
13	Out going groundwater flow through aquifer (m)	0.10	0.09	0.10	0.09

Table 25. Other input parameters for use with SALTMOD

Sl. No.	Parameter	Value
1	Storage efficiency	0.80
2	Depth of root zone	0.50
3	Depth of transition zone	1.50
4	Depth of aquifer	25.0
5	Total pore space of root zone	0.40
6	Total pore space of transition zone	0.40
7	Total pore space of aquifer	0.40
8	Effective porosity of root zone	0.20
9	Effective porosity of transition zone	0.20
10	Effective porosity of aquifer	0.30
11	Initial salt content of the soil moisture (dS/m) at field saturation in root zone/transition zone/aquifer	8.5/10.0/10.0
12	Salt concentration of canal water (dS/m)	0.30
13	Initial depth to water table from ground surface	0.45
14	Critical depth of water table for capillary rise	1.00
15	Leaching efficiency of root zone/transition zone/aquifer	0.70/0.70/1.00

Appendix 6d. Drainage parameters

SaltMod offers the possibility to calculate the drainage capacity factor QH1 (and also a second factor QH2 accounting for the drainage flow above drain level) form the parameters of a subsurface drainage system as explained in the figure below.

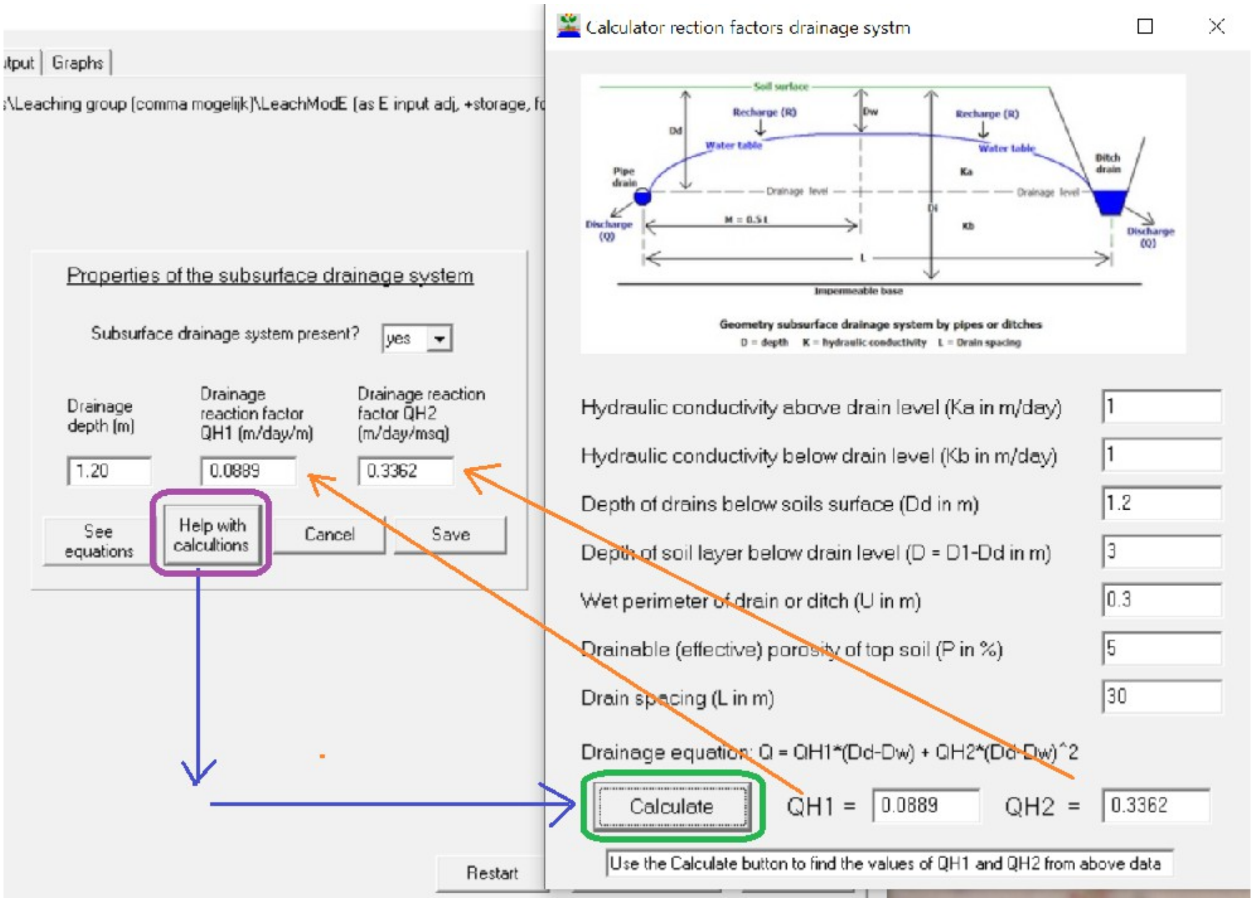


Figure 6d.1. *In the SaltModM input menu opening the panel "Subsurface drainage system present" via the "Drainage system" radio button (see Figure 4) one will see the "Help with calculator button (purple color). Clicking on this button the page "calculator reaction factors drainage system" is opened (right part of the figure). After filling in the drainage parameters, and clicking on the "Calculate button"(green color), the drainage capacity factors QH1 and QH2 are produced and transmitted to the panel (orange arrows).*

The factor QH1 stands for the drainage flow below drain level and QH2 for the flow above it. In the calculation the standard Hooghoudt drainage equation is used. It can be found clicking on the button "See equations" on the panel as shown in Figure. 6d.2 below.

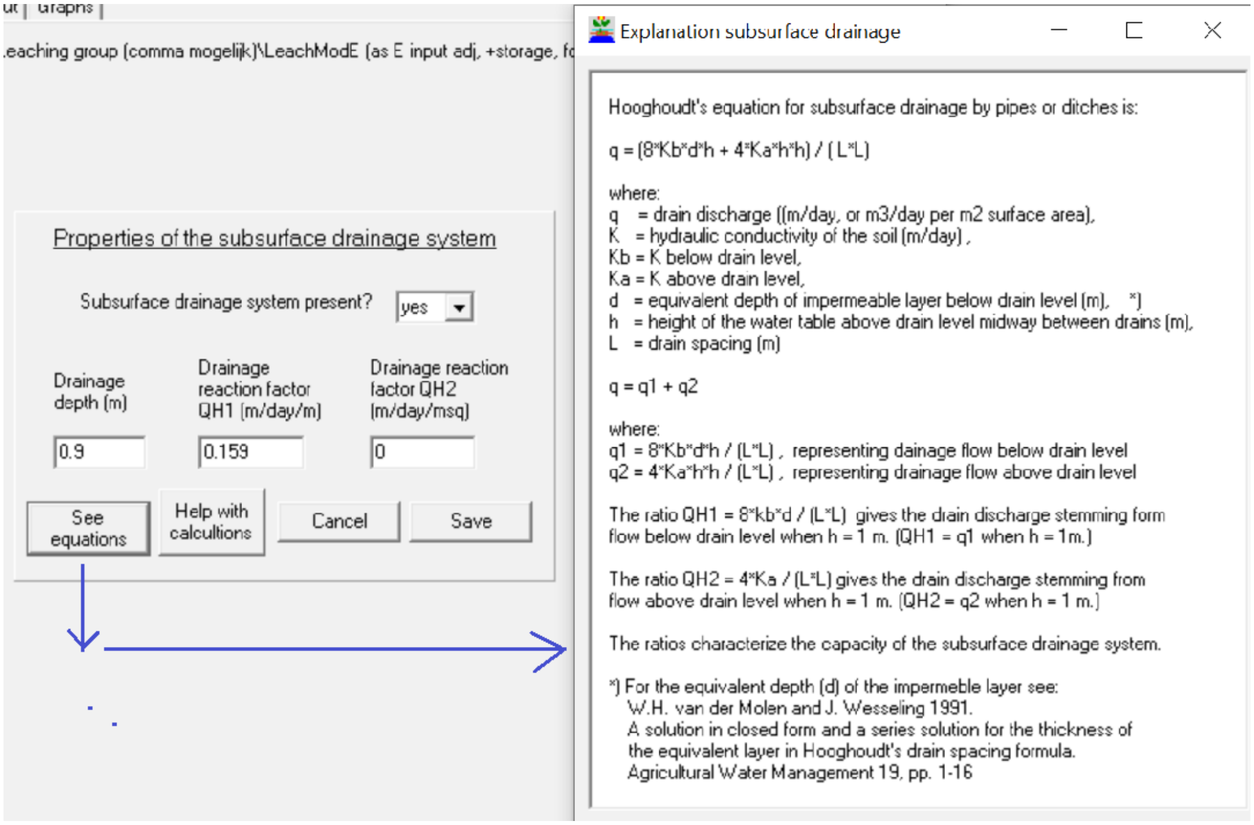


Figure 6d.2. *Clicking on the "See equations" button on the "Subsurface drainage system present" panel, the page "Equations for subsurface drainage is opened and the definition of the Hooghoudt equation is given (blue arrows).*