Menu and user interface of SahysMod, a model for irrigation, drainage, soil salinity, and groundwater management in large project areas divided into polygons

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Abstract
The SahysMod (spatial agro-hydro-soil-salinity model) software can be used to assess the water and soil management in large irrigation projects. For that purpose the user can divide the area in polygons with different cropping, (geo)hydrological and pedological (soil and underground) characteristics. The model can be freely downloaded and applied. A manual exists explaining the principles of the model and the mathematics employed, but a menu with user interface has not yet been published. The present publication compensates this shortcoming.

Contents

1. Introduction

SahysMod (spatial agro-hydro-soil-salinity model) 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 [Reference 1]. It is applicable to large irrigation projects as the area can be divided into polygons, each having more or less uniform characteristics, but these can be different between the polygons. The polygons are interconnected by a groundwater model

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

Within each polygon the principles of the SaltMod model are used [Reference 2].
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.

The mathematics used in the software can be consulted in a manual [Reference 3].

SahysMod has been used and tested extensively. A selection of reports and publications on the use of SahysMod exists [Reference 4].

2. General parts of the user interface

The general part of SahysMod's user menu is shown in the next figure.

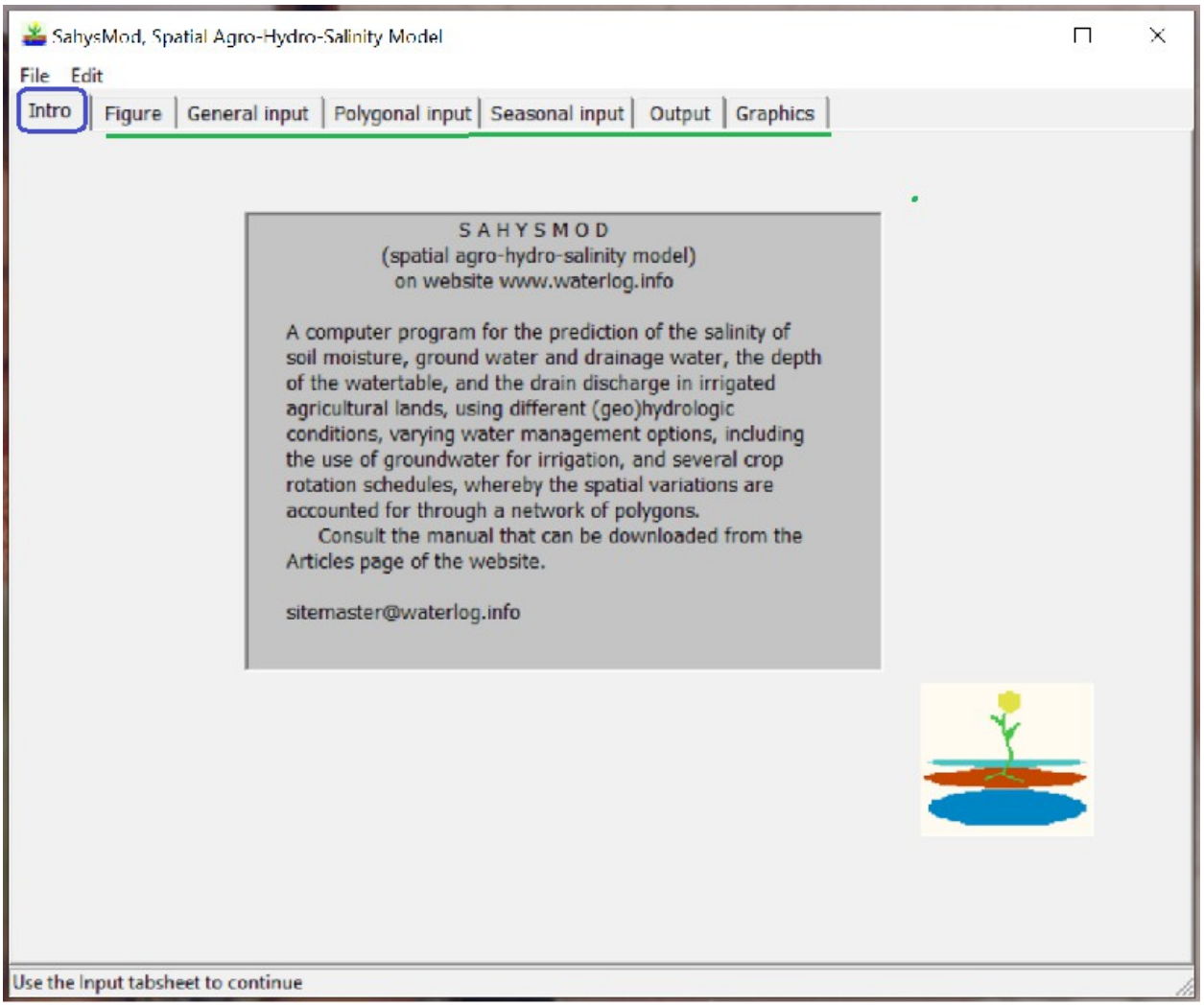


Figure 1. *After opening the software, the introduction tab sheet is shown (blue square). Further there are tab sheets for the figure, the general input, the polygonal input, the seasonal input, the output, and the graphics (see the green line).*

Clicking on the "Figure" tab sheet reveals a sheet as depicted in the following picture. It shows the hydrology, the irrigation canal system, ground water use, and three soil layers as used in each of the polygons, though specific characteristics may differ between the polygons.

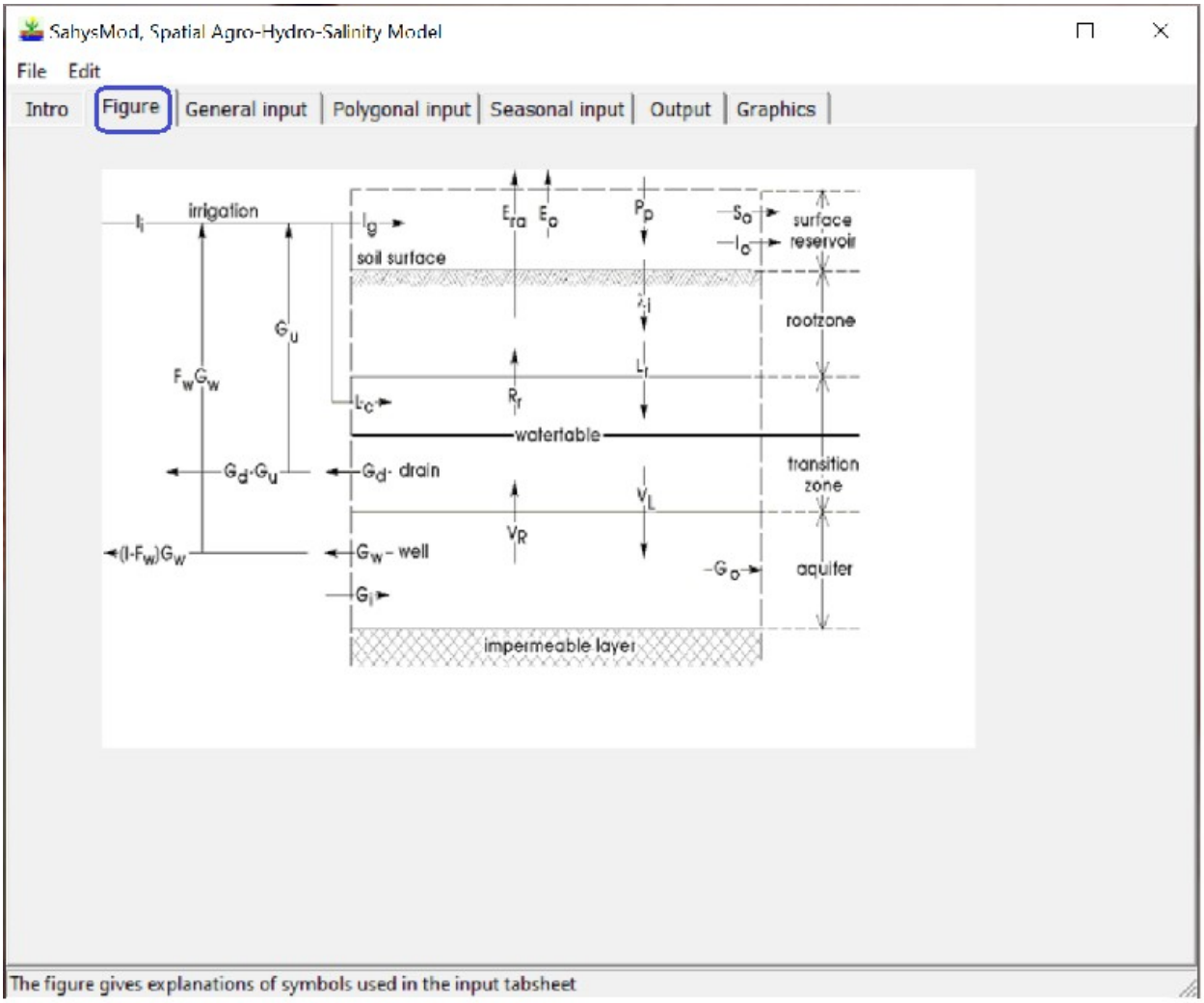


Figure 2. *The "Figure" tab sheet is opened (blue square). It gives a schematic overview of the physical elements used in the polygons of SahysMod. It shows the hydrology, the irrigation canal system, ground water use, and three soil layers as used in each of the polygons, though specific characteristics may differ between the polygons.*

The general input tab sheet is presented in *figure 3*.

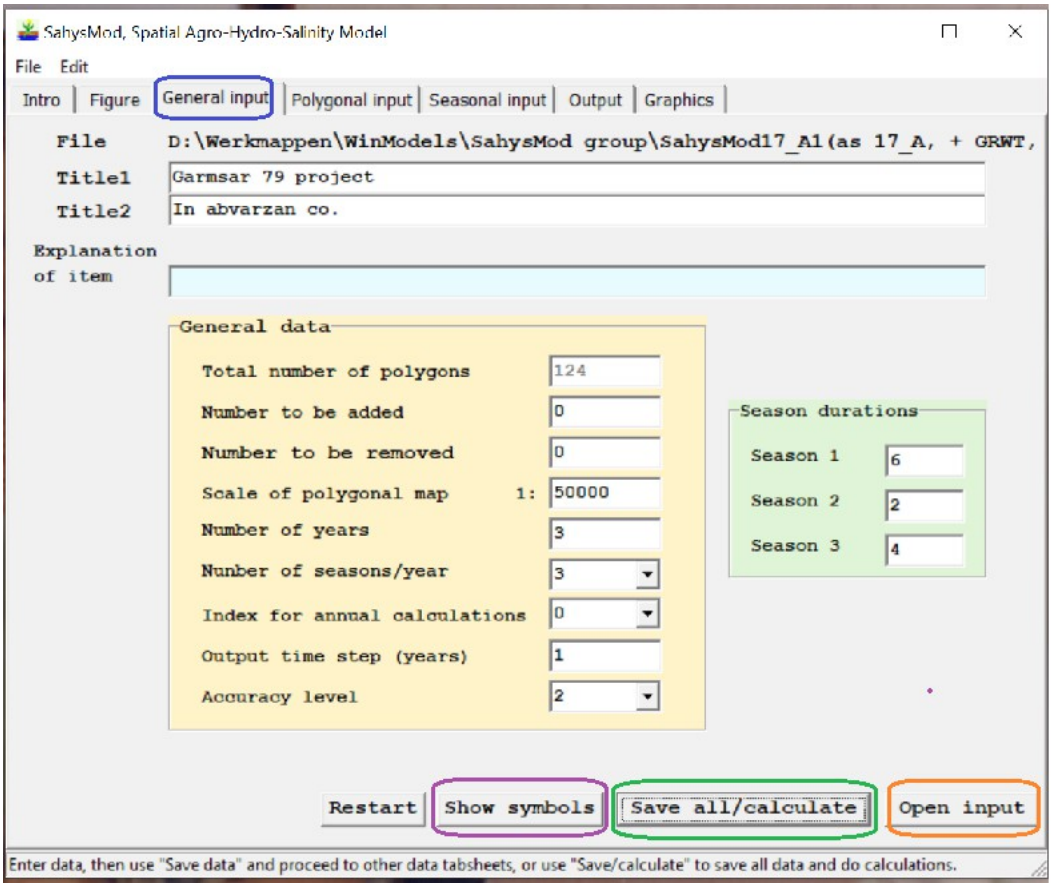


Figure 3. *Overview of the general input tab sheet (blue square). It has been produced by clicking on the "Open input file" button (orange square), giving the general data of an existing input file, but this group can also be used for a new input file. The "Show symbols" button produces a list of all symbols used in this program, also in the "Figure" tab sheet depicted just before. When all the input data have been properly entered, the "Save all/calculations" button (green square) will make the program to save the data and start the calculations.*

The next figure depicts the opening of the "Polygonal input" tab sheet.

3. The polygonal input menu

The next figure depicts the opening of the “Polygonal input” tab sheet.

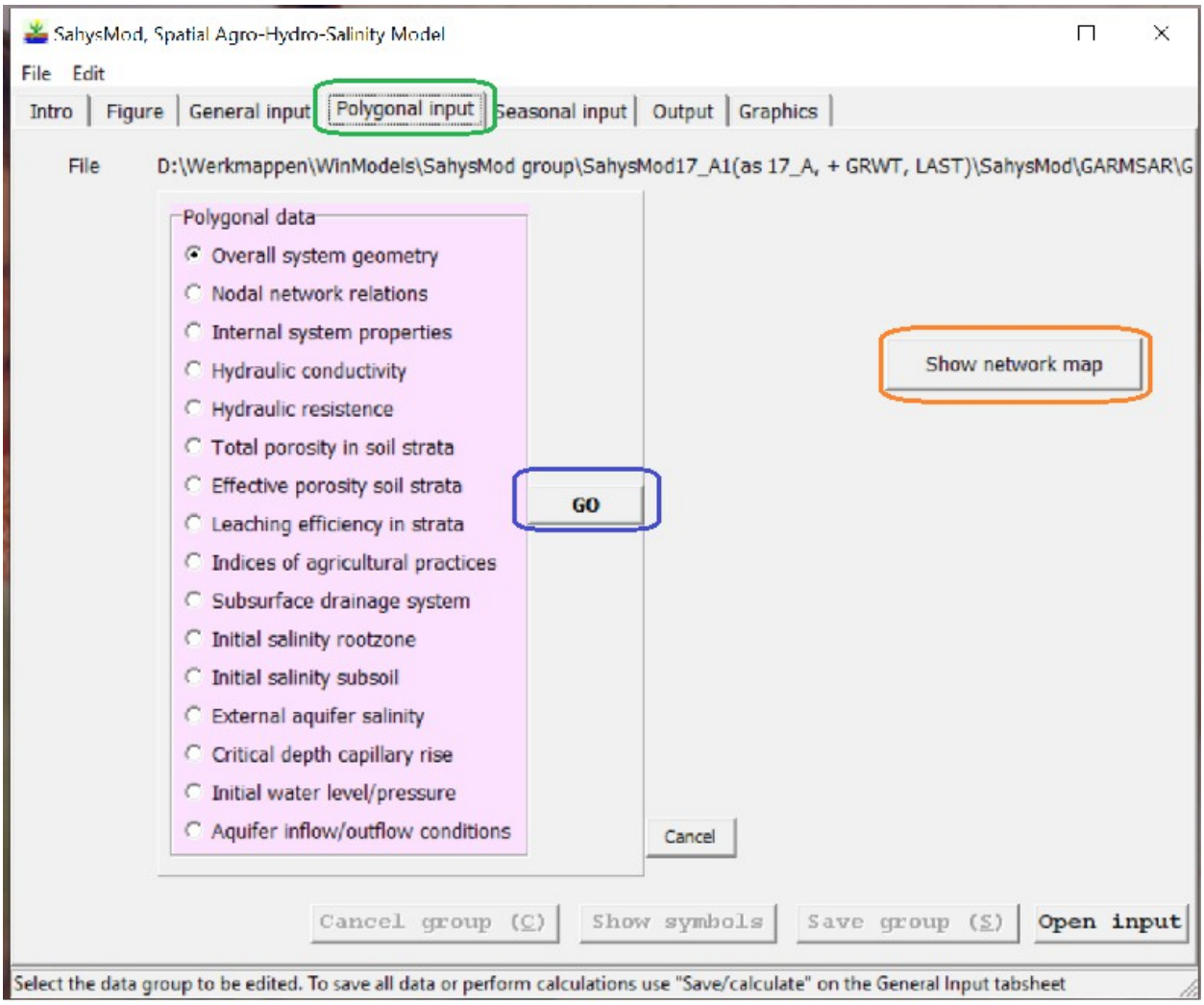


Figure 4. *The “Polygonal input” tab sheet (green square) reveals a table (rose colored) with items concerning the data that need to be known for each polygon. The selection in this figure is “overall system geometry” Clicking the “Go” button (blue square) will give the details of the geometry required. The “Show network map” button (orange square) will provide a picture of the polygonal network employed.*

The following figure will demonstrate the geometry data, while the figure thereafter comes with the network picture.

In this manual it would be too much too show all the possible selections of polygonal data properties, so the view of the next two figures are considered representative for the remaining items.

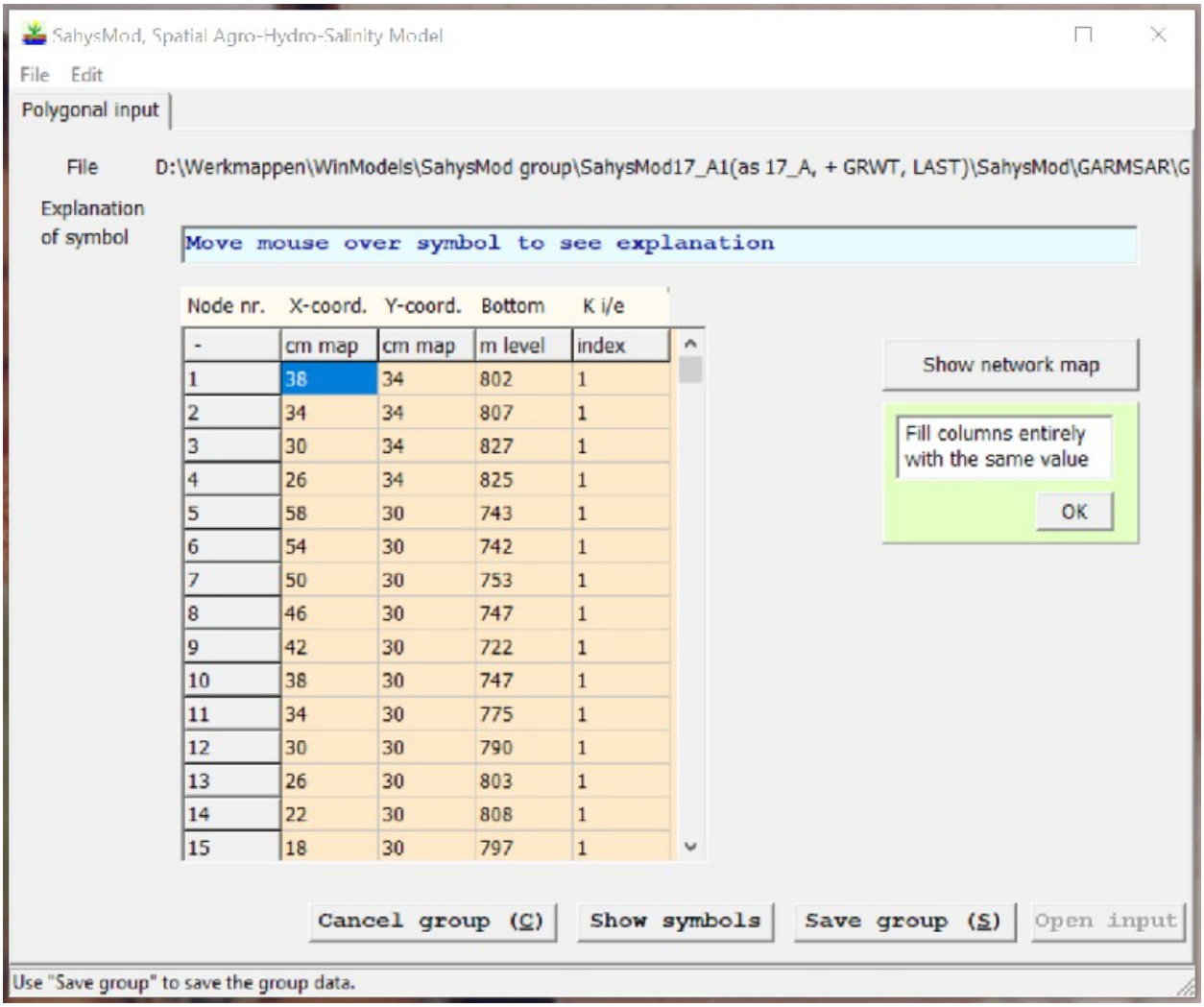


Figure 5. *The geometry data filled in for each polygon. There X and Y coordinates, level of the bottom of the aquifer and the K index, which stands for the key of rotational type of agricultural land use, K = 0, 1, 2, 3 or 4. The explanation of the K index can be found clicking on the "Show symbols" button.*

As this example concerns an existing input file, it cannot be seen how SahysMod helps to determine the polygonal network and the coordinates of its nodal points. Anyway, this will be discussed in the Appendix to this paper.

The next picture shows the polygonal network employed in this example.

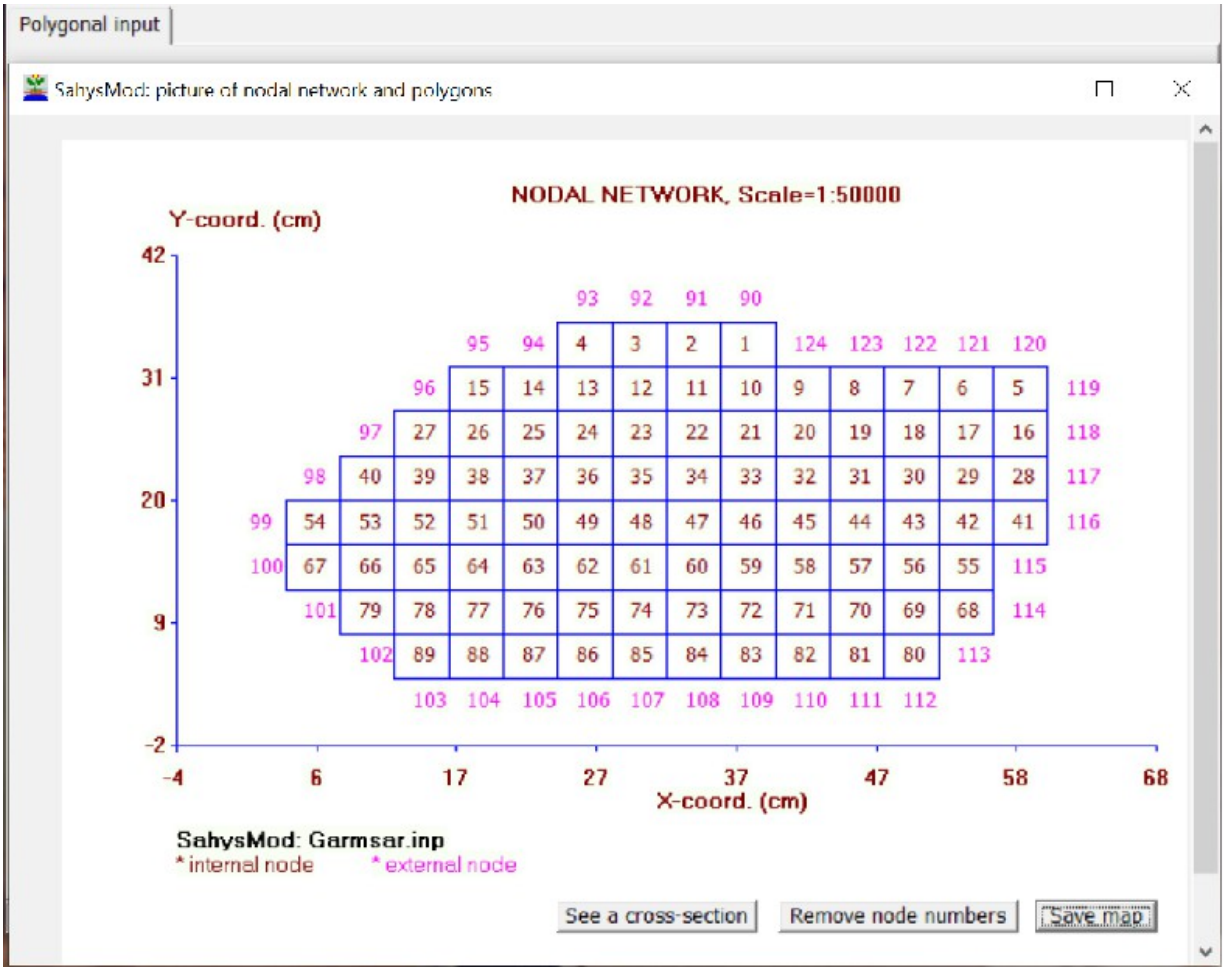
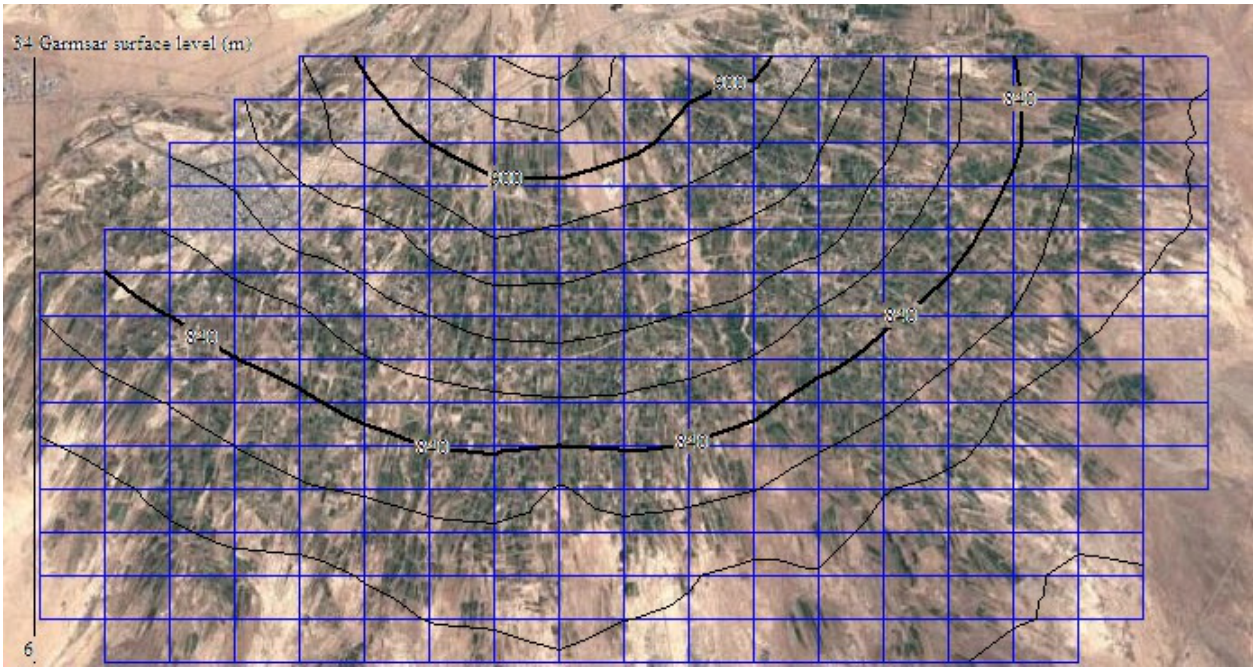


Figure 6. *Picture of map of the network of the polygons. There 89 numbered internal polygons (blue) and 35 external polygons defining the boundary conditions (purple numbers) making a total of 124 polygons. The map gives the possibility to "See a cross-section" over those polygons in a straight line wanted by the user. It is also possible to reduce the size of the network with the "Remove node numbers" button.*

This map helps to visualize the node numbers mentioned in *figure 5*.

The coordinates of the node numbers are expressed in cm on the scale of the map defined in *figure 3* and shown on the top of this *figure 6*.



The Garmsar alluvial fan (Google Earth) overlain by the SahysMod nodal network (blue lines) and the surface level contour lines (black) made with the QuikGrid program.

When clicking on the “Seasonal input” tab sheet on obtains a picture as can be seen in *figure 7*.

4. The seasonal input menu

The seasonal input user interface looks as follows:

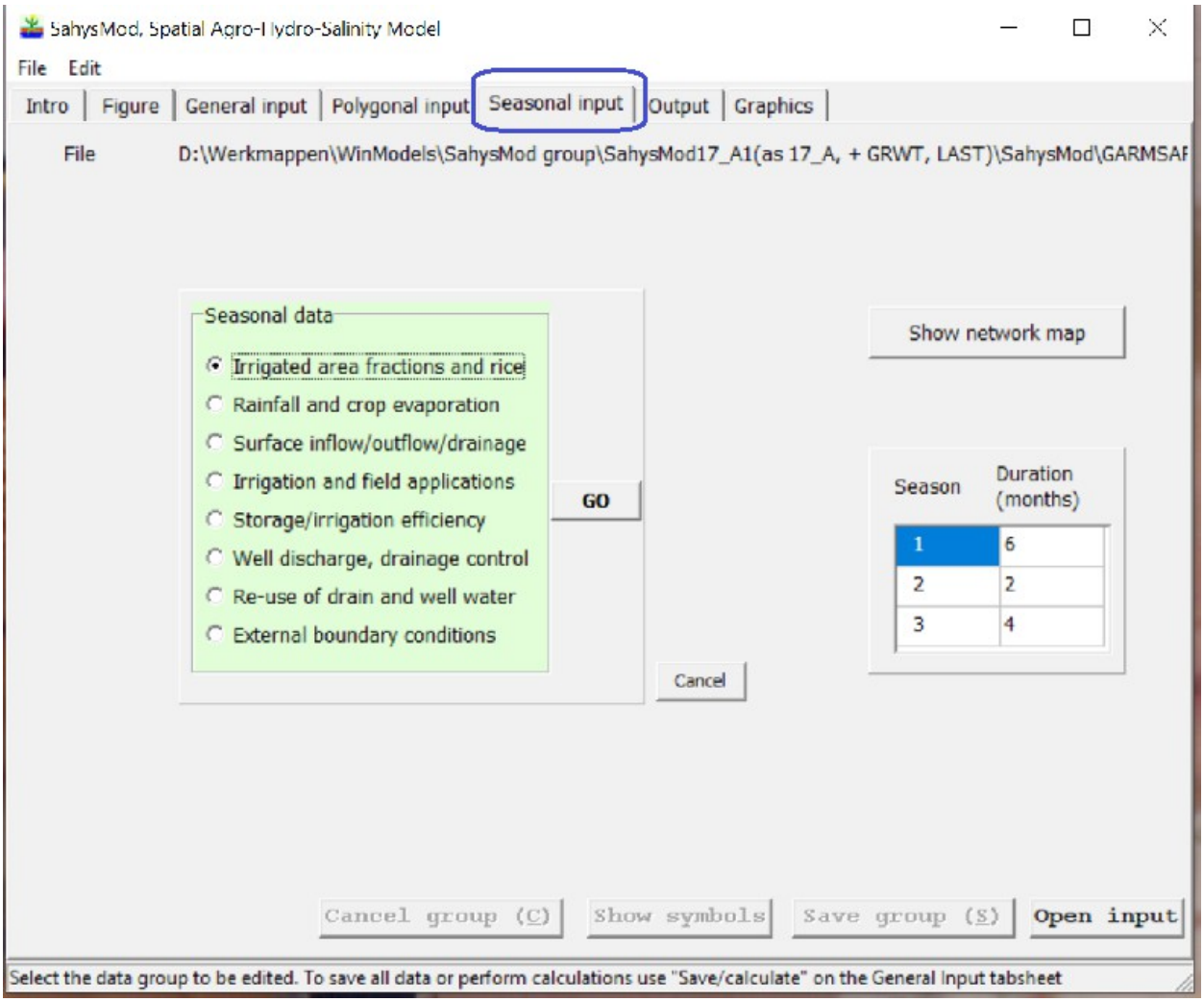


Figure 7. *The SahysMod "Seasonal input" tab sheet (blue square) contains the seasonal data for each polygon. It can be seen that in this case the model uses three seasons in a year, as is also evident in* figure 3..

There are 8 groups of data (green table) of which the "Irrigated area fractions" are being selected. Clicking on the "Go" button will produce the corresponding table as demonstrated in *figure 8* below.

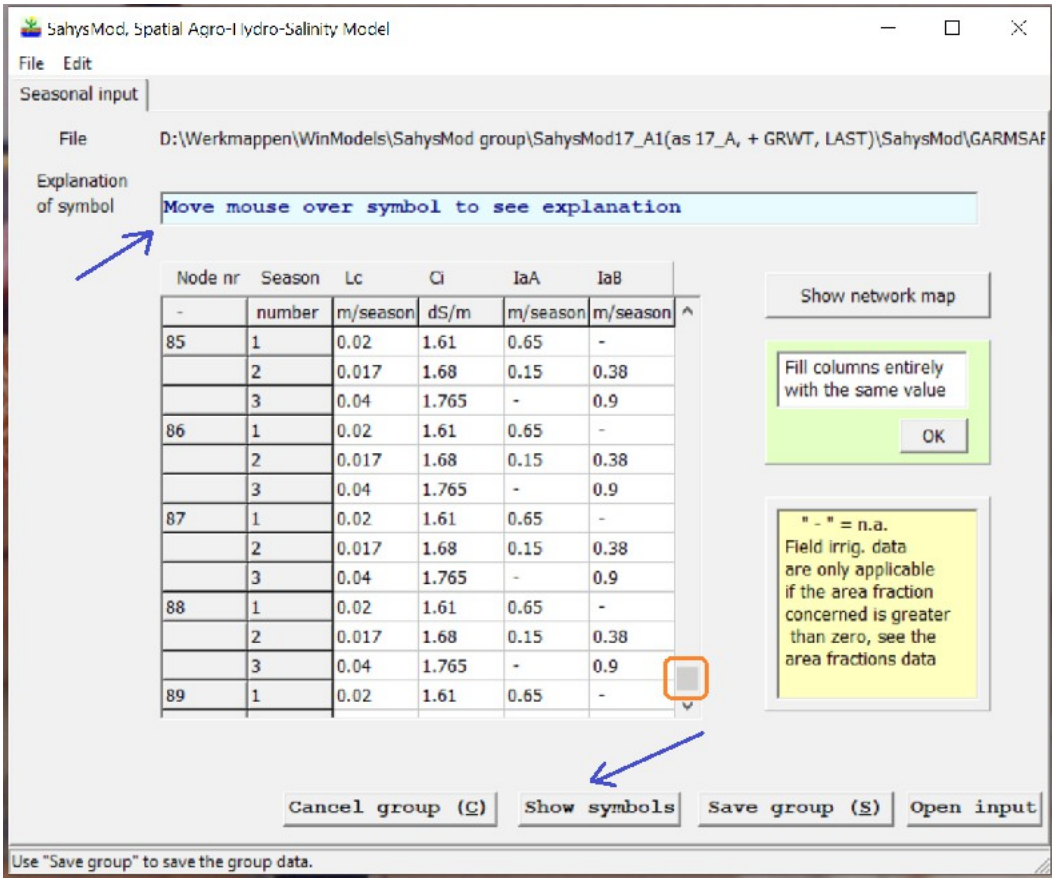


Figure 8. *Table of irrigation data. There are two ways to find the meaning of the symbols used (blue arrows). In this picture the seasonal irrigation data are shown for polygons 85 to 88 because the scroll bar (orange square) has been moved down.*

In this paper it would be excessive to show the tables for all the seasonal data groups, and therefore we proceed to the "Output" tab sheet that is created when clicking on the "Save all/calculations" button, see *figure3*. This button should only be pressed after all the input data have been properly entered. Before SahysMod starts with the calculations, the data will be checked and saved. In case the data check detects one or more errors, a message will be given to correct these before the calculations can be done.

The output menu can make data groups, graphs and maps. This is explained in the section 5.

5. The output menu, tables, graphs and maps

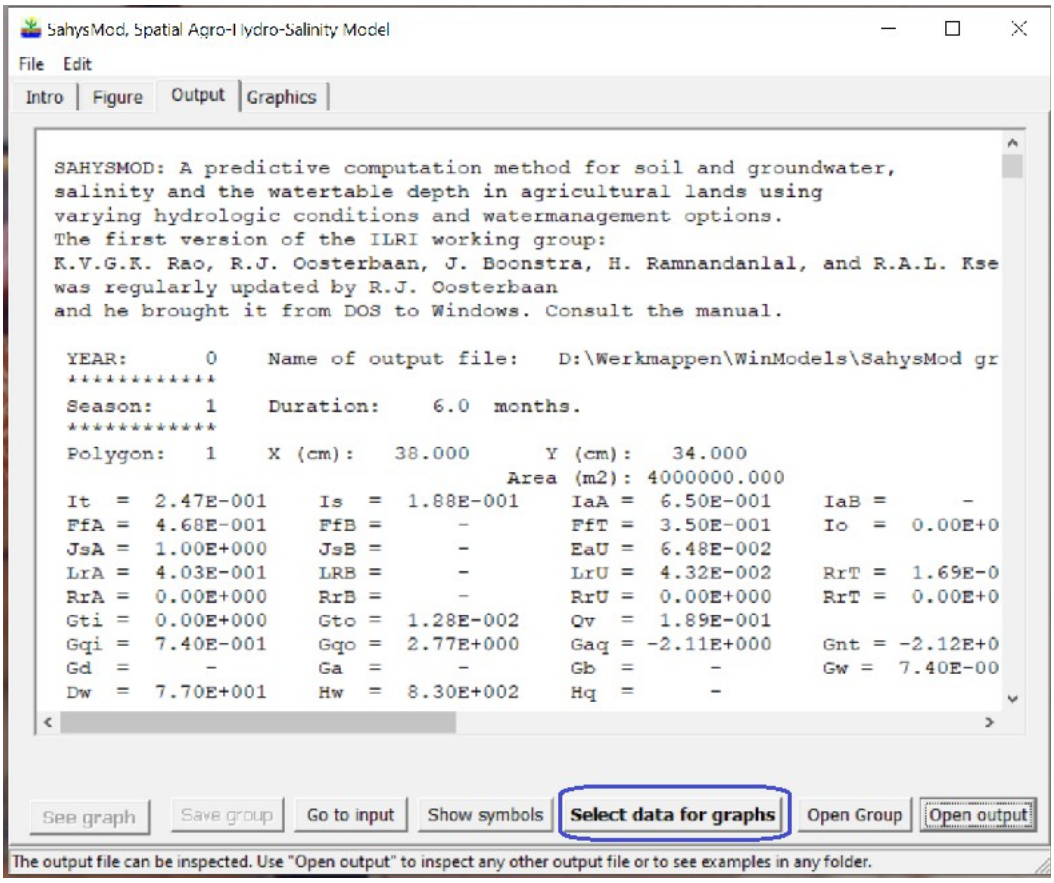


Figure 9. *Overview of the top of the output file. The file can be further inspected using the scroll bars. The output file is quite big and its inspection is tedious. Therefore the possibility exists to inspect the output per group and see their graphs using the "Select data for graphs" button (blue square).*

When the selection button has been clicked upon, the output groups appear in the next figure.

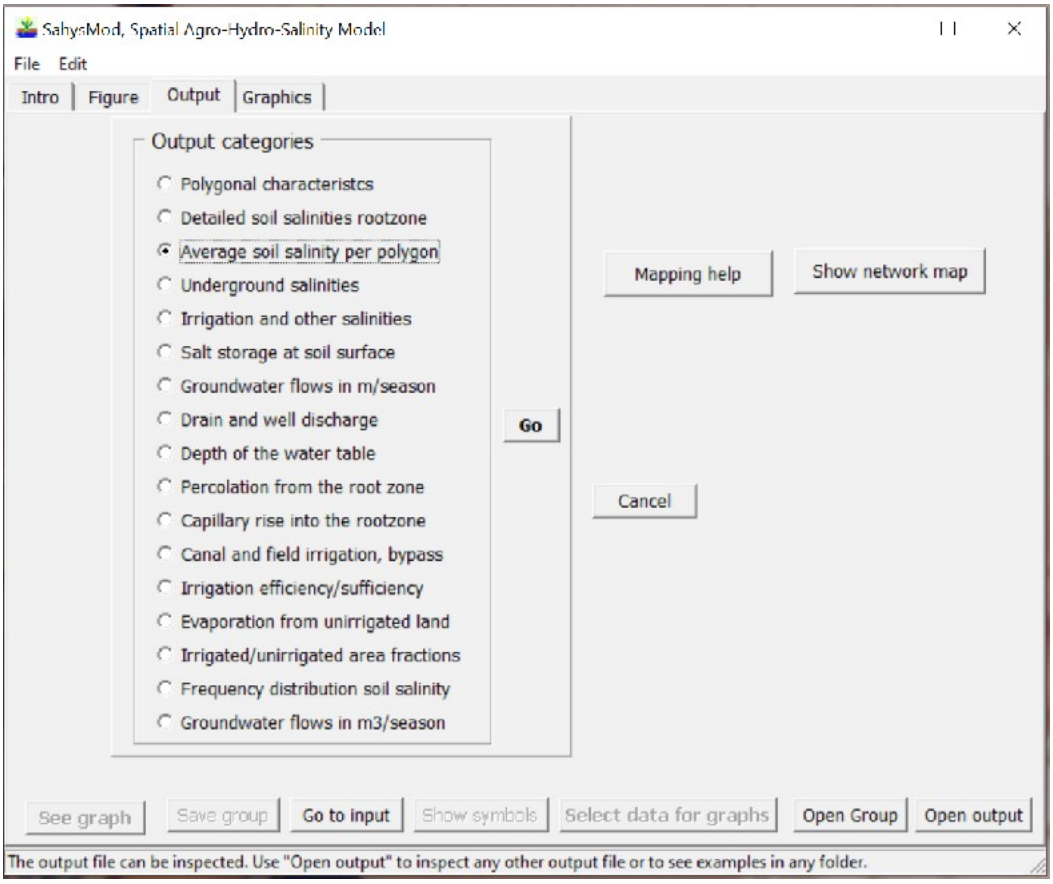


Figure 10. *Overview of the selection options of groups of output data. In this example the "Average soil salinity per polygon" has been selected. To proceed with this selection, click the "Go" button.*

When the "Go" button has been clicked, one will see a choice between inspection of all the polygonal data at a certain time, meaning at a certain season in a certain year, or all the time data of a certain polygon, See the following figure.

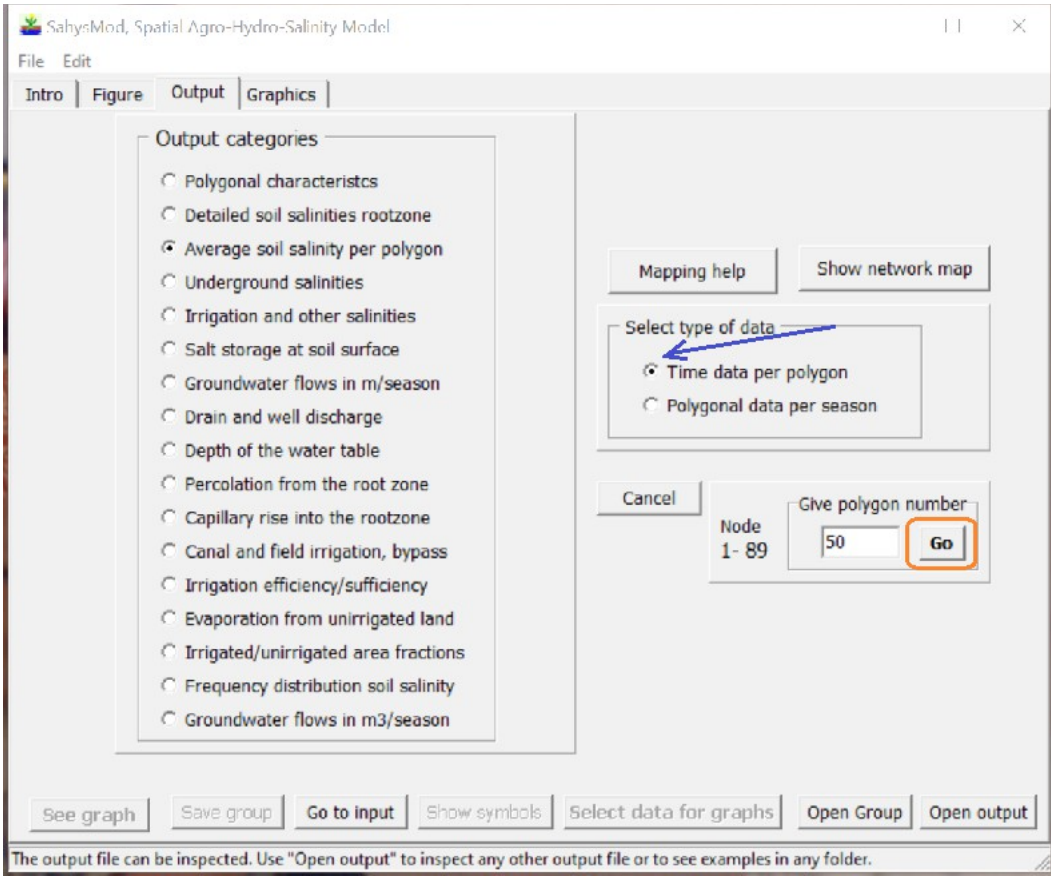


Figure 11. *After clicking the "Go" button in* figure 10*, a choice can be made either to inspect all the time data of a certain polygon, or all the polygonal data at a certain time, meaning at a certain season in a certain year. In this example the time data have been chosen (blue arrow), as well as polygon number 50 of the 89 polygons in total. To inspect this data group, the "Go" button (orange square) will have to be clicked upon.*

Having clicked on the "Go" button the selected data group appears as visible in the next figure.

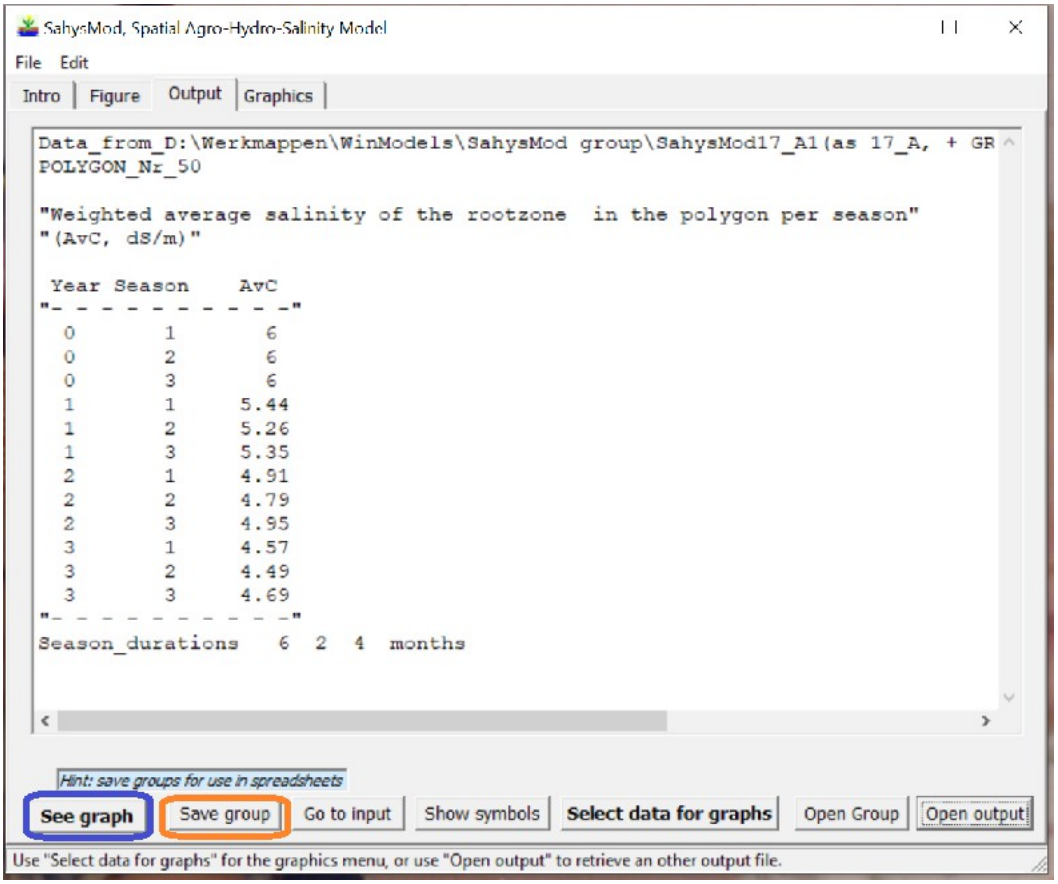


Figure 12. *The average soil salinity data for polygon 50 over the time (three years with three season each) is presented here.*

The group can be saved as a *.prn file (orange square) for further use, for example for import into a spreadsheet program like Excel (take care to import separated by space).

Also a graph of the data can be seen clicking on the “See graph” button. The result of this action is presented in the figure on the following page.

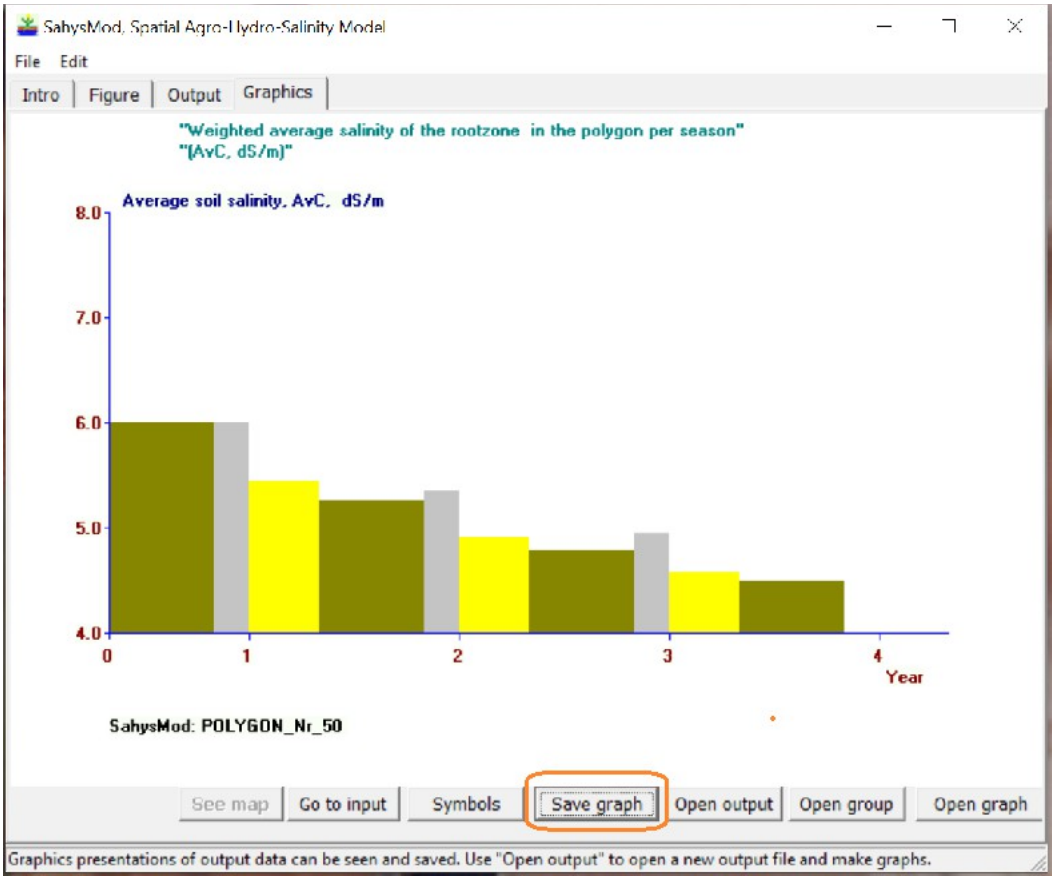


Figure 13. *Graph of the average soil salinity (AvC) of polygon 50 with time. The color of the salinity in the first season of each year is yellow color, the second season (which is of larger duration) in green, while the third season (which is of shorter duration) is depicted in gray color. It appears the soil salinity is descending with time.*

In *figure 11* a choice was seen either to inspect all the time data of a certain polygon, or the polygonal data at a certain time, meaning at a certain season in a certain year, and the first choice was made. Let us see what happens when the second choice is selected.

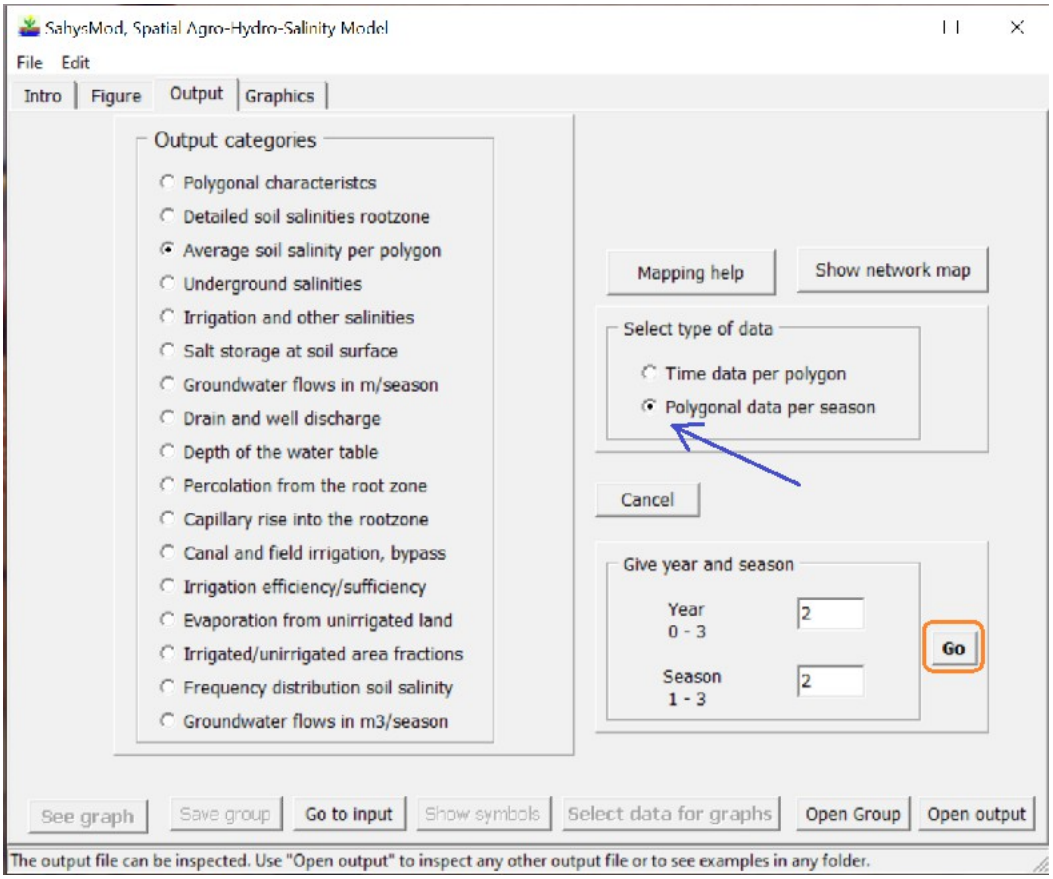


Figure 14. *Instead of the choice "Time data per polygon" in figure 11, here the option "Polygonal data per season" is chosen (blue arrow) and the season selected is the second one (of three) in the second year (of three).*

Clicking the "Go" button (orange square) produces the list of soil salinities as demonstrated in *figure 15*.

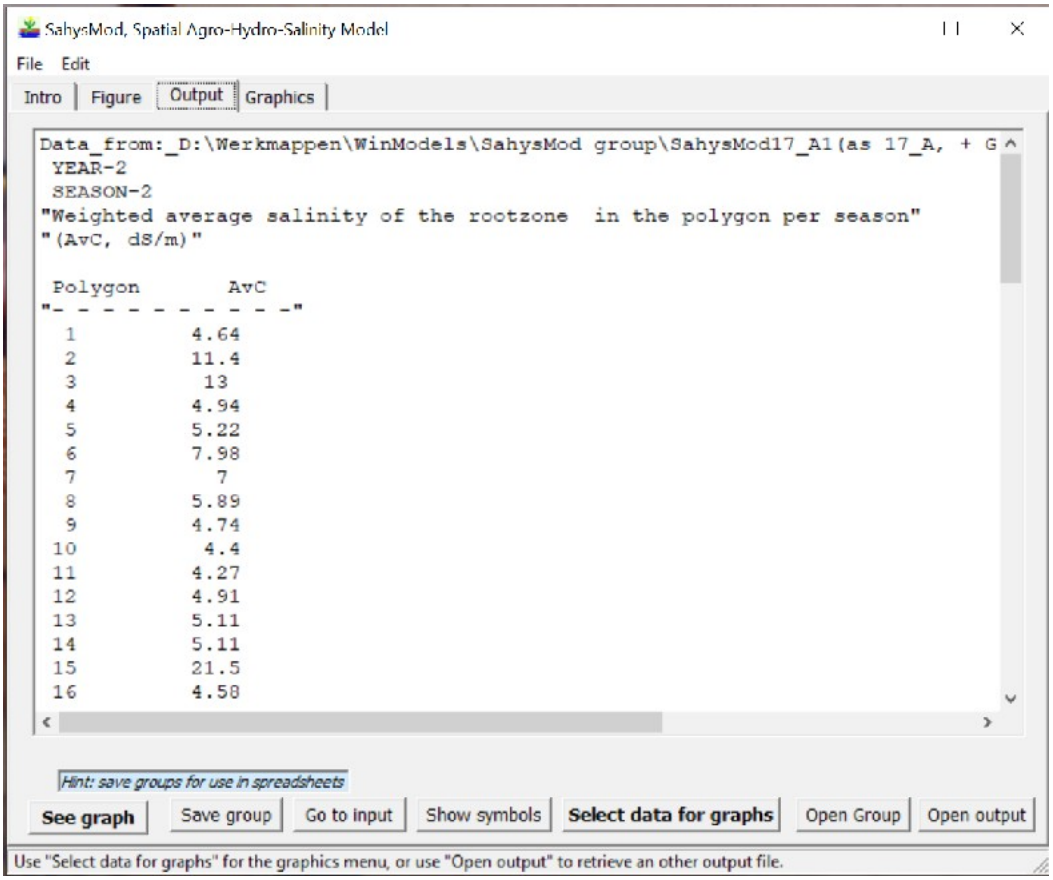


Figure 15. *List of average soil salinities (AvC) per polygon in season 2 of year 2 as determined in* figure 14.

Clicking on the “See graph” button makes the graph visible as in *figure 16*.

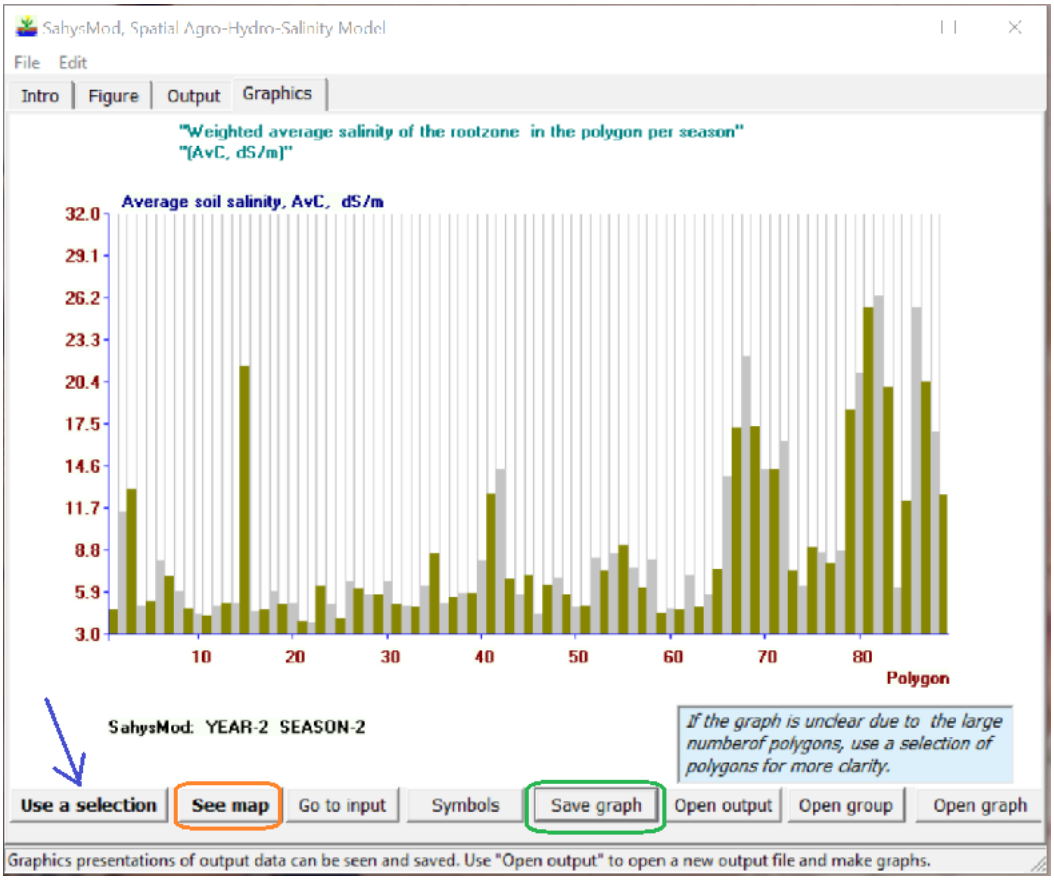


Figure 16. *Graph of the average soil salinity (AvC) of all the polygons (1 to 89) as selected in* figures 14 *and* 15.

In some cases this graph is not clear, though here it is. In that case a cross-section over the polygonal map can be employed, see the announcement in light blue and the arrow in dark blue.

The map can be produced clicking the “See map” button (orange square). Also in this case, the mapping procedure can be carried out in different ways as explained in the figure on the next page.

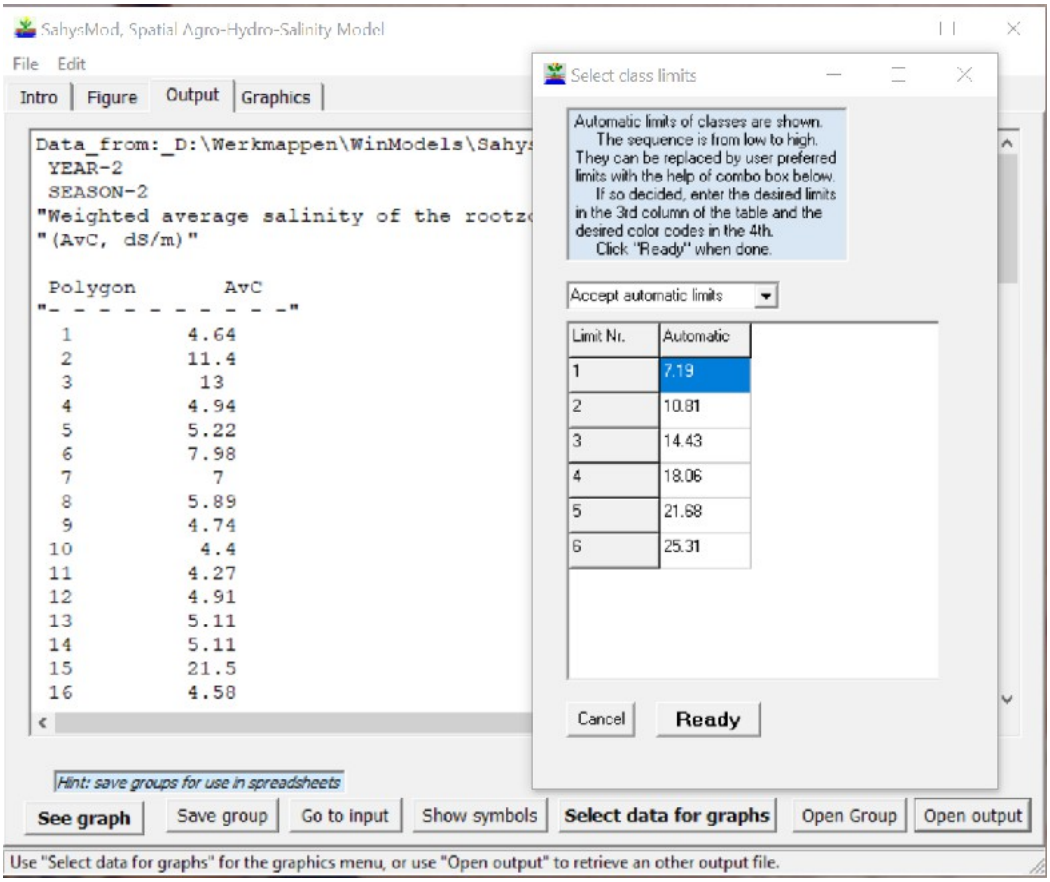


Figure 17. *This figure is like figure 15, but is has an insert to the right, indicating that the map will be made automatically with salinity class limits as given in the table.*

In Appendix B it is explained how the map can be made manually with a determination of the number of classes, the class limits and the corresponding colors to be handled.

Clicking on the “Ready” button in the insert results in a map as illustrated in the next figure.

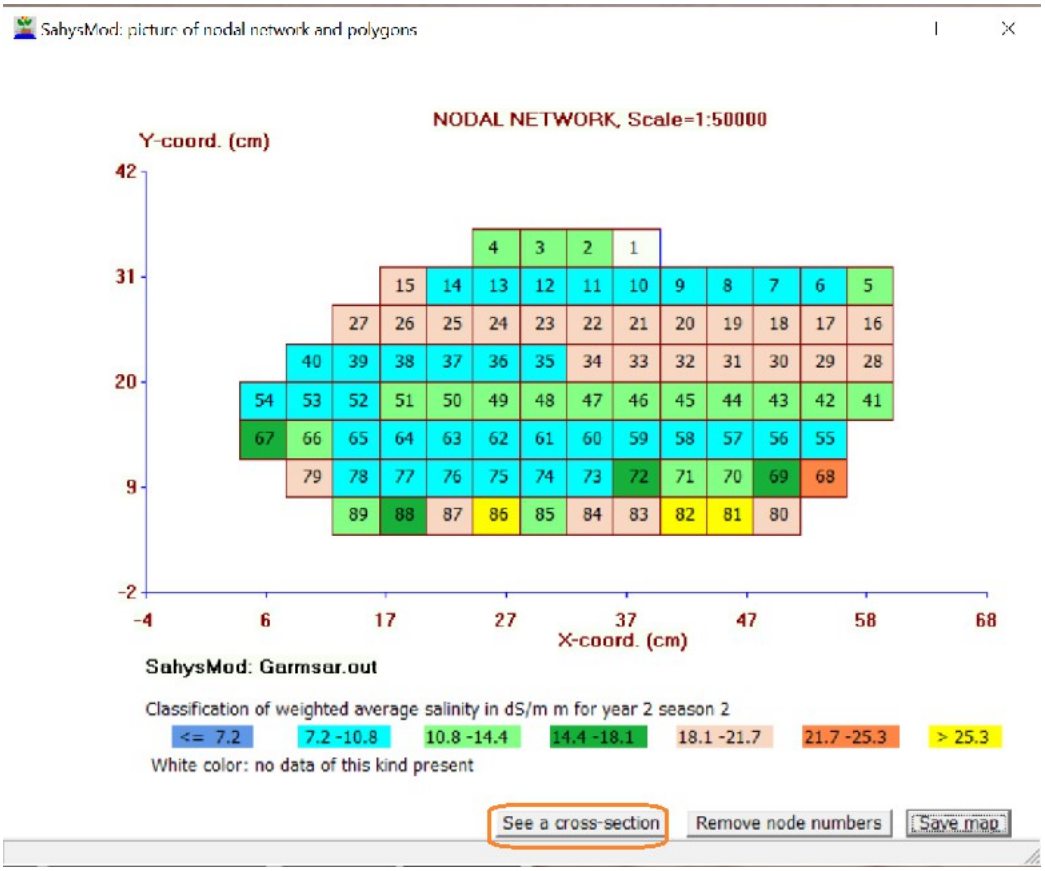


Figure 18. *Map made automatically with the data demonstrated in the previous figure and concerning season 2 of year 2 as determined in* figure 14.

The highest salinities (yellow) occur in the polygons with high polygonal number in the bottom line. Yet, salinities smaller than 7.2 dS/m (dark blue) are not present, meaning that the soil salinity in the area is generally quite high.

The button “See a cross-section” (orange square) helps to determine a sequence of polygons (for example diagonally 5, 17, 30, 44, 58, 72, 84) for which a graph can be made as visible in the selection table of figure 19.

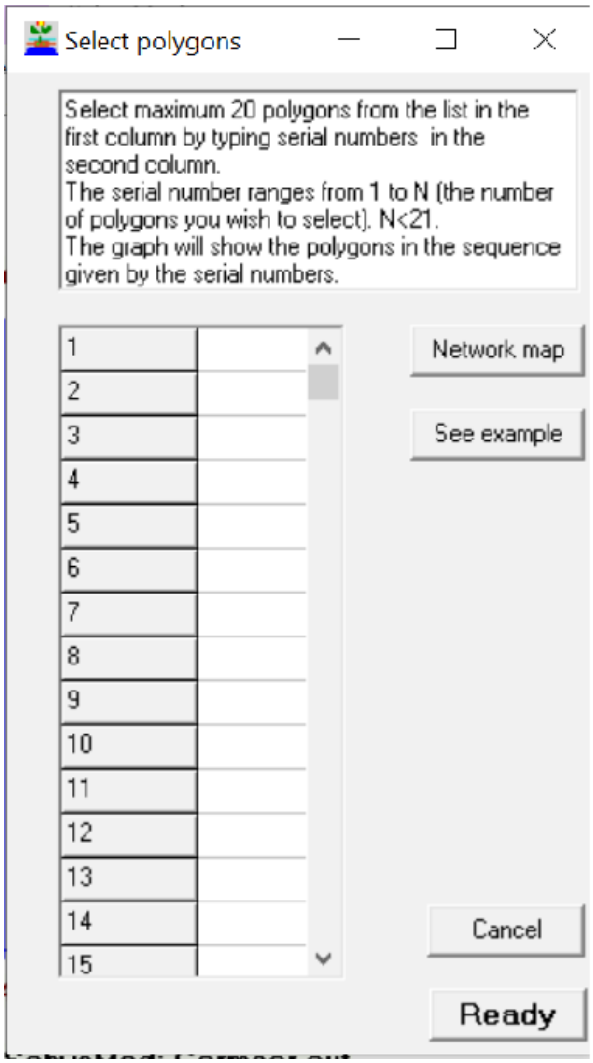


Figure 19.

Table for the selection of polygon numbers in a cross-section over the area that must be included in the graph to be made.

As a second and final example of a polygonal map, the net groundwater flow (incoming flow from neighbor polygons into the central polygon less outflow from the central polygon to neighbor polygons) is used in Figure 20.

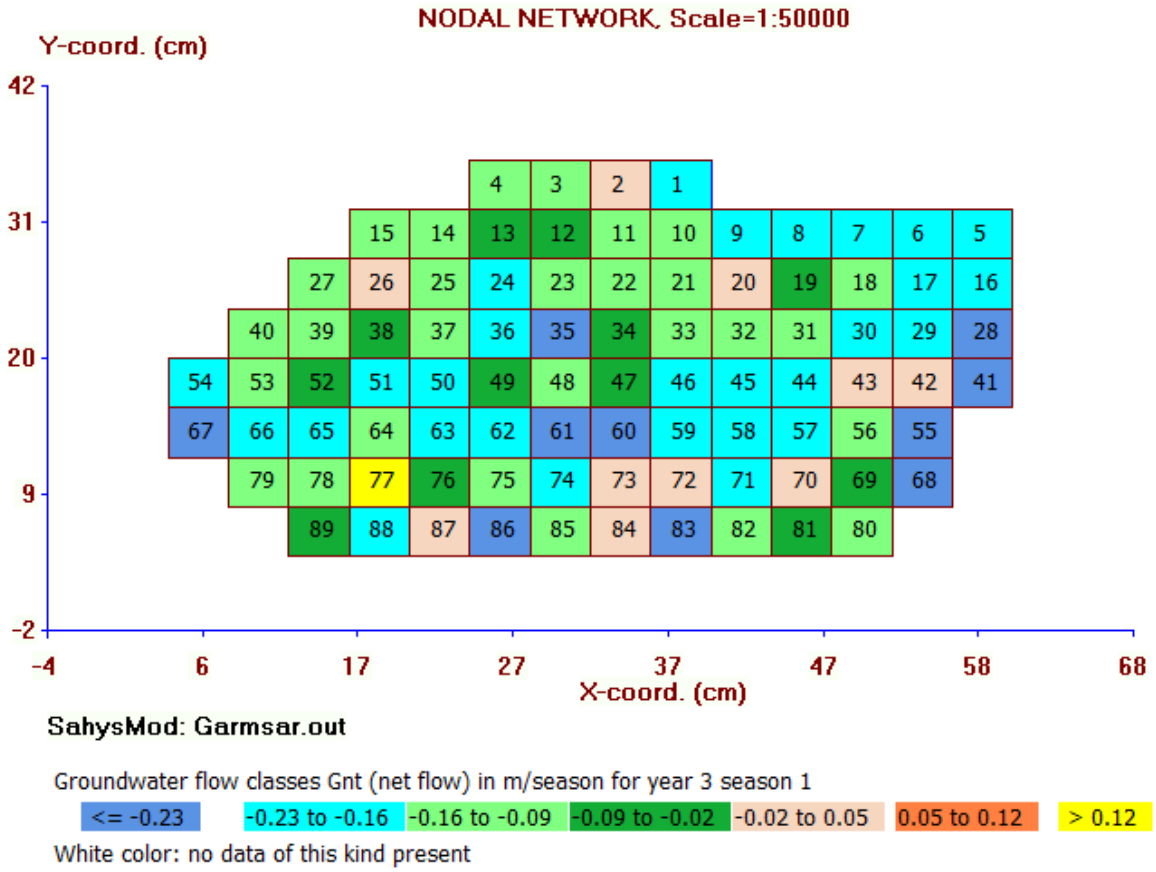


Figure 20. *Polygonal map of the net groundwater flow (Gnt, incoming flow through aquifer and transition zone from neighbor polygons into the central polygon less outflow through aquifer and transition zone from the central polygon to neighbor polygons).*

Most polygons have negative Gnt value signifying that more water goes out than comes in owing to the polygonal recharge by rainfall and irrigation. Only polygon 77 (yellow) receives net inflow. It probably lies in a depressed area that should be apparent on the topographic map.

For a definition of the zones mentioned see *figure 2*.

7. Conclusions

The SahysMod model covers many aspects of land and water management of irrigation project. If the technicians of an irrigation project would set up SahysMod for their project area, they would have a good overview of the conditions. The model could also be updated any time that new or corrected data become available so that the value of the model would increase. Also, when project changes have been made, the might be incorporated in the model so that it keeps it value. Further when project changes are proposed, their consequences could be assessed and evaluated.

For more information on SahysMod, the list of publications in which the model is used can be consulted [reference 4]. The following publications could also be consulted:

1. Agro-hydro-soil-salinity characteristics of the irrigated Garmsar alluvial fan, Iran, described with the SahysMod model [*reference 5*].
2. Irrigation, groundwater, wells, drainage and soil salinity control in the alluvial fan of Garmsar, Iran – assessments with the Sahysmod model [*reference 6*].
3. The groundwater hydraulics of the Garmsar alluvial fan, Iran, assessed with the SahysMod model [*reference 7*].
4. Mapping facilities of the spatial agro-hydro-soil-salinity model SahysMod [*reference 8*].

7. References

Reference 1.
SahysMod (spatial agro-hydro-soil-salinity model) can be freely downloaded from:
https://www.waterlog.info/sahysmod.htm

Reference 2.
SaltMod model software and computer program. Free download from:
https://www.waterlog.info/saltmod.htm

Reference 3.
The principles and mathematics used in the SahysMod model can be consulted in:
https://www.waterlog.info/pdf/sahysmod.pdf

Reference 4.
List of publications in which the use of SaltMod is reported. Download from:
https://www.waterlog.info/pdf/sahyslist.pdf

Reference 5.
Agro-hydro-soil-salinity characteristics of the irrigated Garmsar alluvial fan, Iran, described with the SahysMod model

Reference 6.
Irrigation, groundwater, wells, drainage and soil salinity control in the alluvial fan of Garmsar, Iran-assessments with the Sahysmod model

Reference 7.
The groundwater hydraulics of the Garmsar alluvial fan, Iran, assessed with the SahysMod model

Reference 8.
Mapping facilities of the spatial agro-hydro-soil-salinity model SahysMod

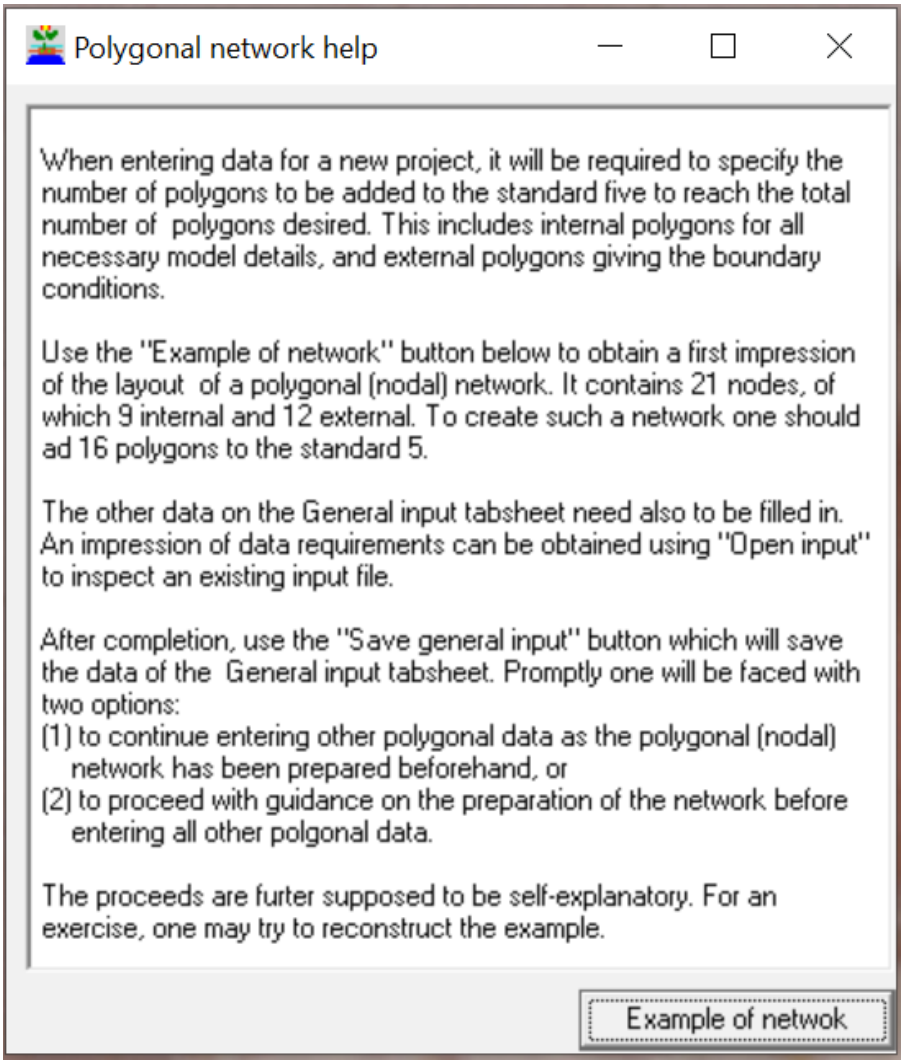
8. Appendices

This section contains three appendices:

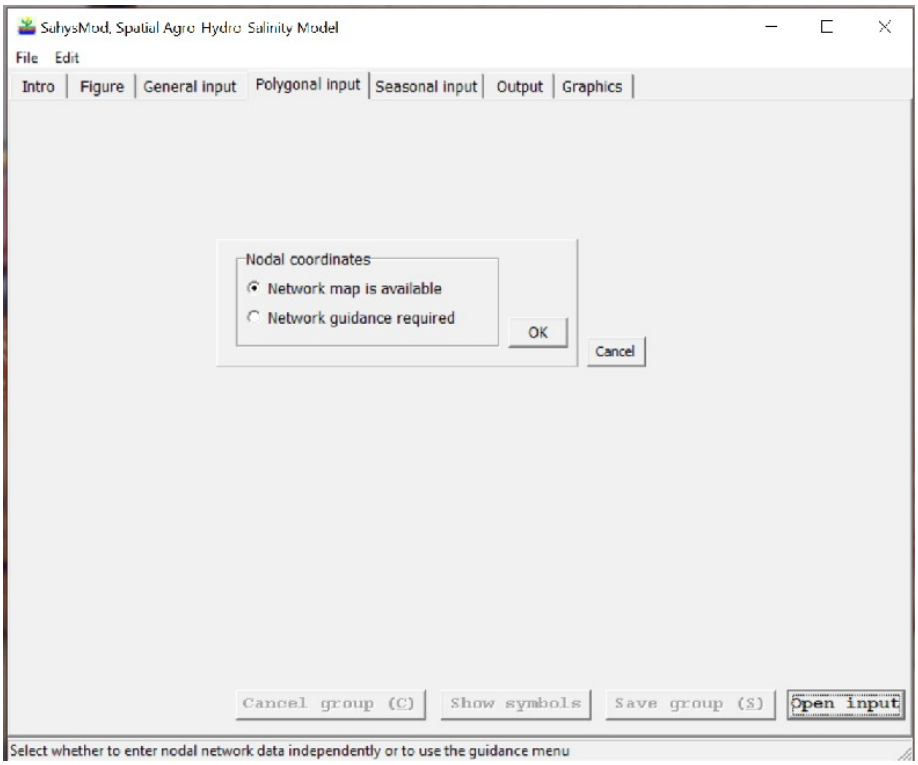
Appendix A. SahysMod's aid in nodal network construction
Appendix B. Manual selection of output item classes and map colors
Appendix C. Relations between topographic level. soil salinity, depth of water table, capillary rise, and hydraulic conductivity of the aquifer.

Appendix A. SahysMod's aid in nodal network construction

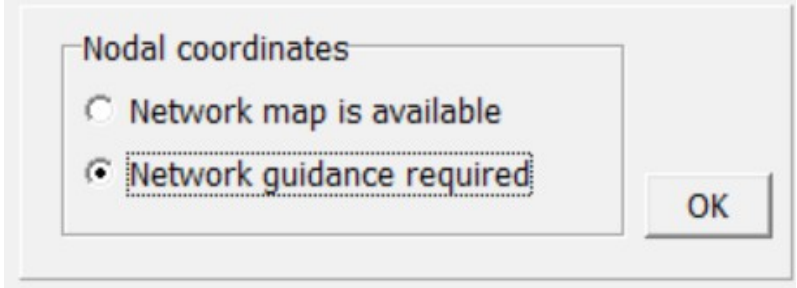
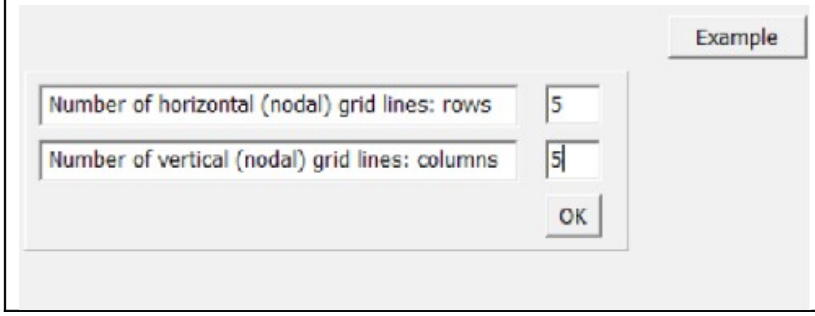
When starting a new input file, the "Input" tab sheet has a "First Aid" button that, when clicked on, shows the next advisory text:

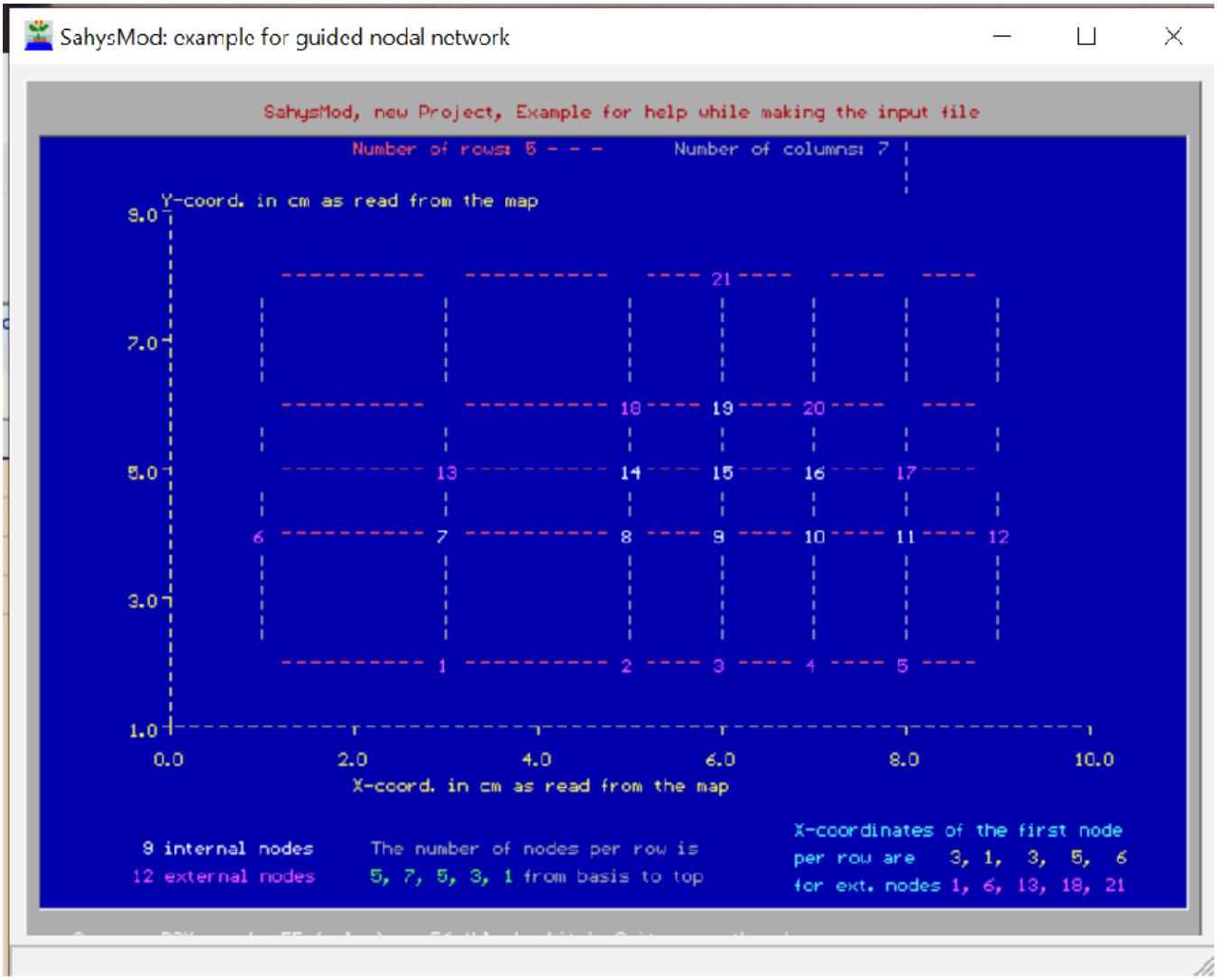


When, after completion of the general data (see figure 3), the "Save general input" button has been clicked, the following picture is shown:



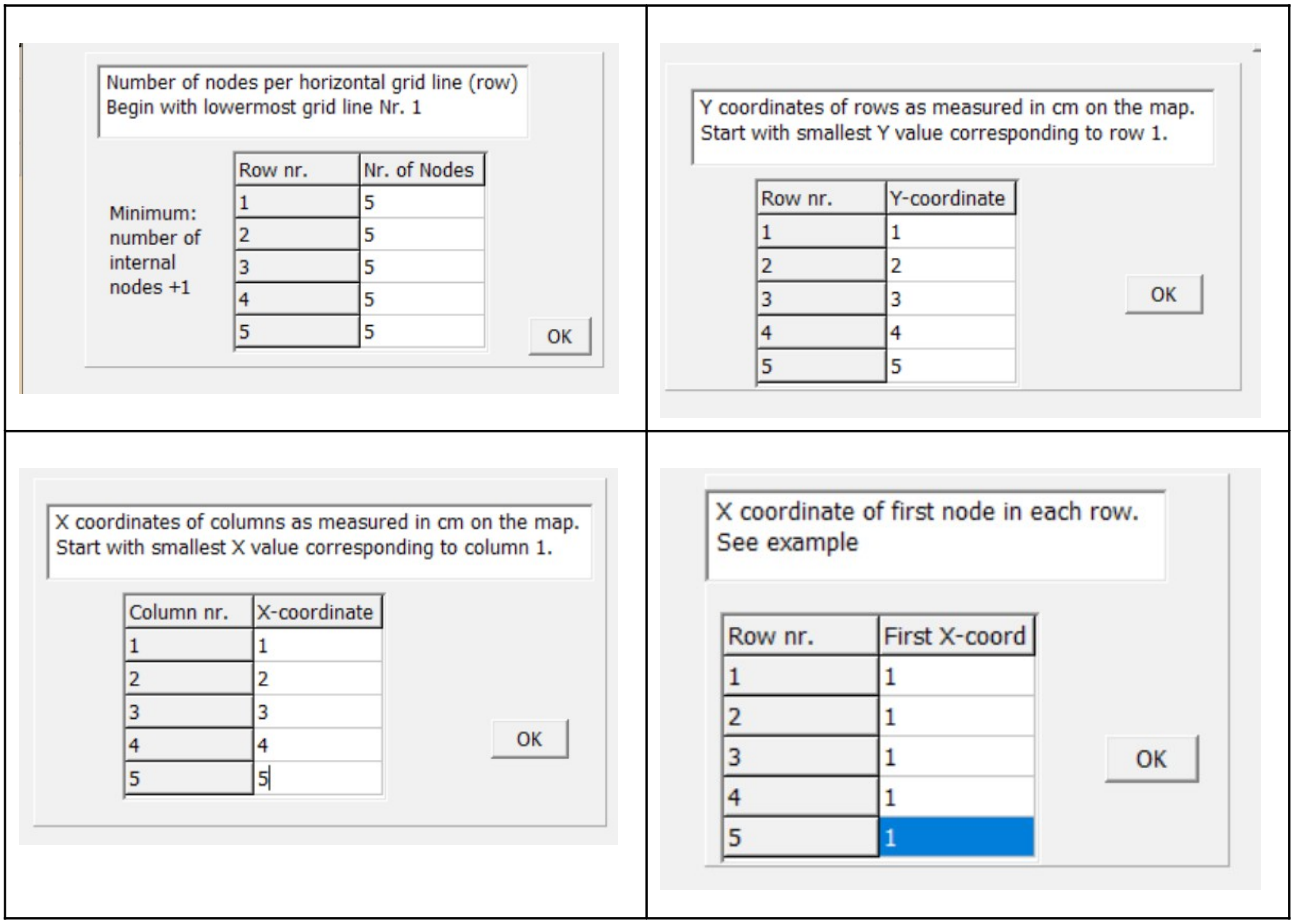
An enlargement of the central block in the previous figure, with the "Network guidance required" option selected, is given in the next picture:

	*After activating the "OK" button, one will see a block asking for the number or rows and columns,* *See left under in this table.*
	*To make the examples not too complicated, only 5 rows and 5 columns are filled in.* *Clicking the "Example" button, the next figure appears.*



From this figure on gets the impression how the horizontal and vertical grid lines are formed, how the horizontal X and the vertical Y coordinates are depicted and that there will be internal polygons, indicated by white nodal numbers, and external polygons, indicated by purple colored nodal numbers. The nodes are the centers of the polygons to be formed.

Further the following information will be asked sequentially:



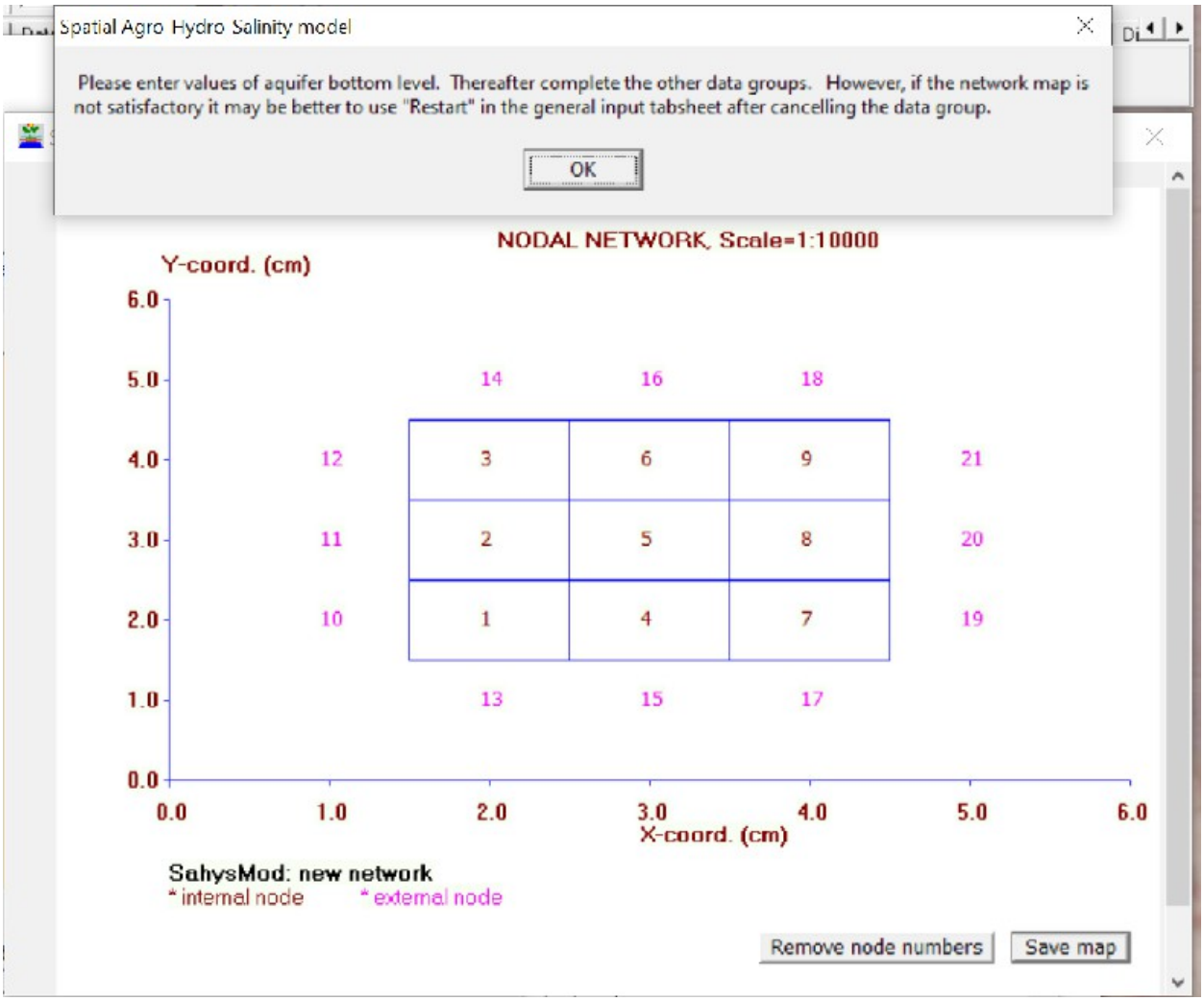
Each table follows after clicking the "OK" button of the previous table.

The table right under asks for the first X-coordinate per row.

In the example (the blue figure above) the first X-coordinate in the first row, pertaining to Node 1, is 1. The first X-coordinate in the second row, pertaining to Node 6, is 0. The first X-coordinate in the third row, pertaining to Node 13, is 1. The first X-coordinate in the fourth row, pertaining to Node 18, is 2. Lastly, the first X-coordinate in the fifth row, pertaining to Node 21, is 3.

The table right under is more simple, all first nodes have the same X-coordinate begin 1.

After the last "OK" click, the following picture appears, showing the polygonal network that has been created with the data previously provided.



This picture shows the polygonal network that has been created with the data previously provided.

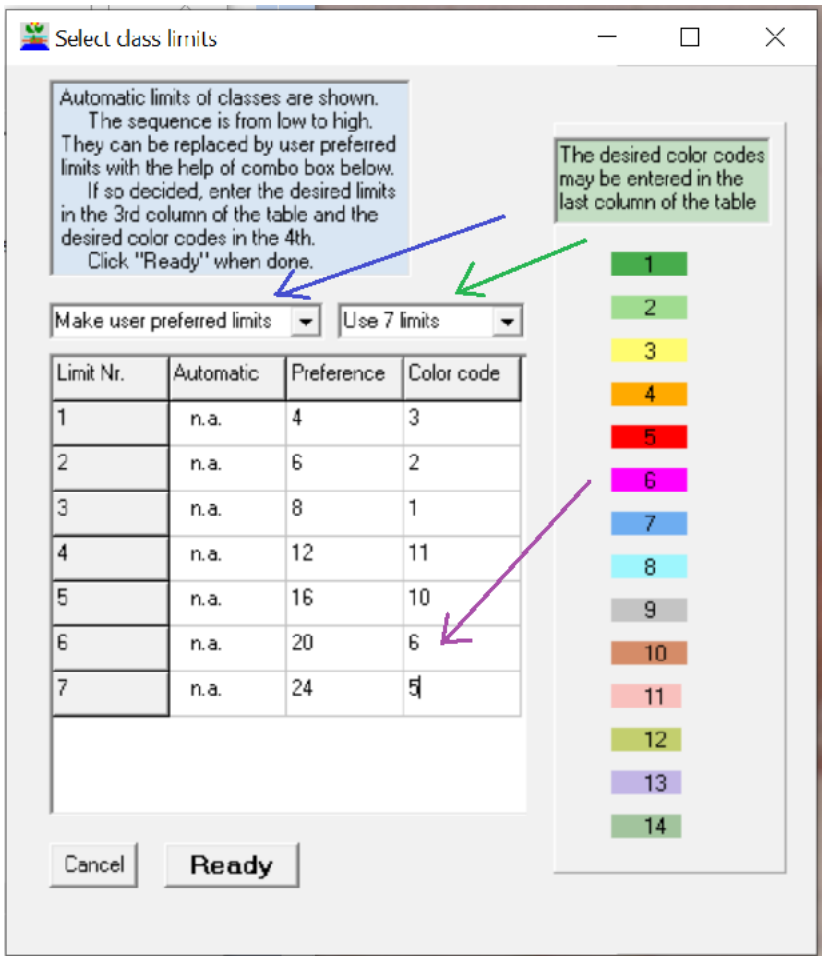
The message on top announces that the levels of the aquifer bottom in each polygon must be completed (see for example *figure 5*).

Hereafter the SahysMod aid will help to complete all the other polygonal data as appears in figure 4.

Appendix B. Manual selection of output item classes and map colors

In figure 17 the classification and coloring of the map of the output item selected was indicated as automatic.

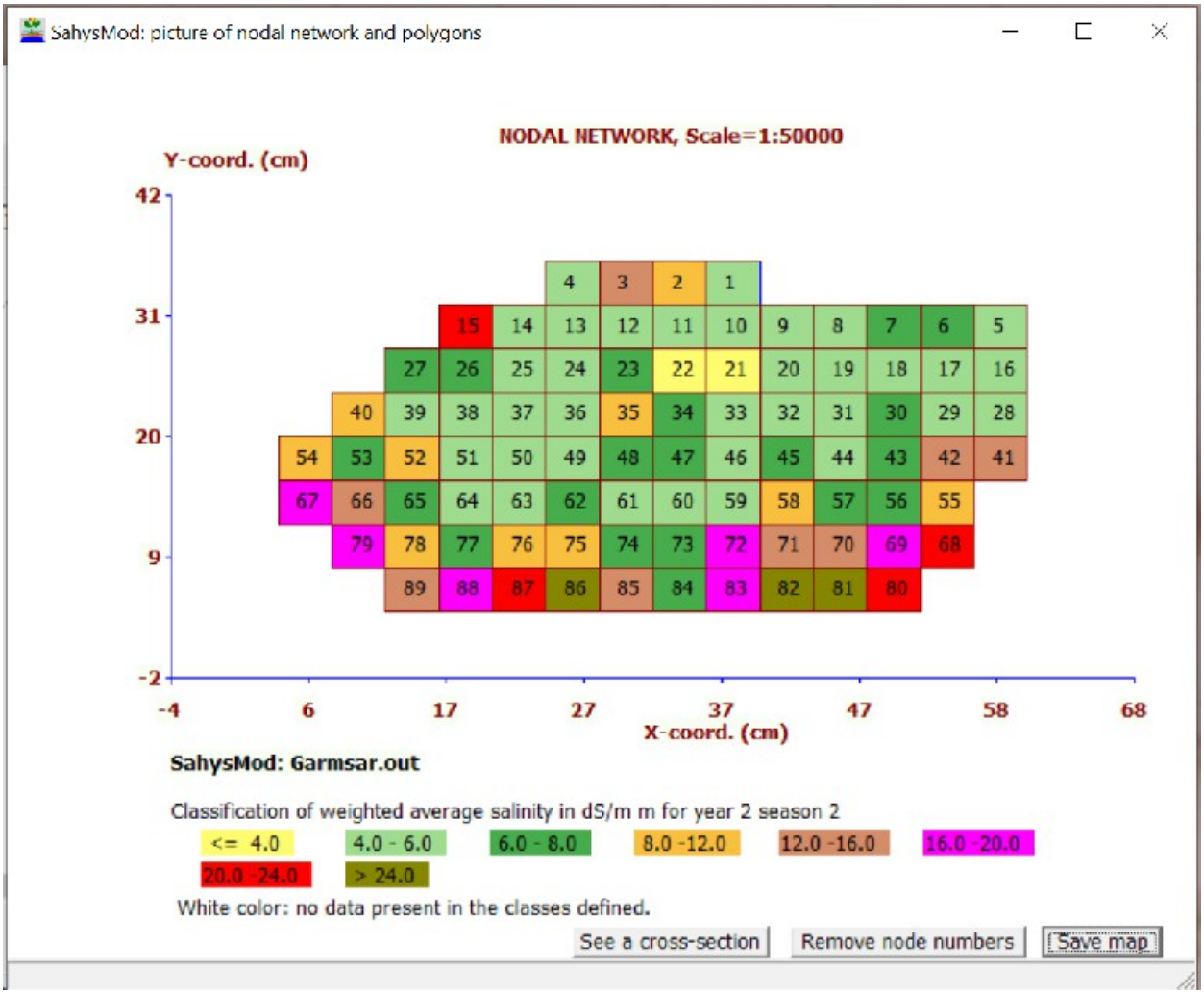
However, it is also possible to follow the preferences of the user as clarified in the illustration hereunder.



Instead of the automatic procedure demonstrated in figure 17*, the user can prefer the "Make user preferred limits" option (blue arrow). He can also define the amount of class limits (green arrow), define the limits themselves (third column) as well the colors desired (see for example the purple arrow).*

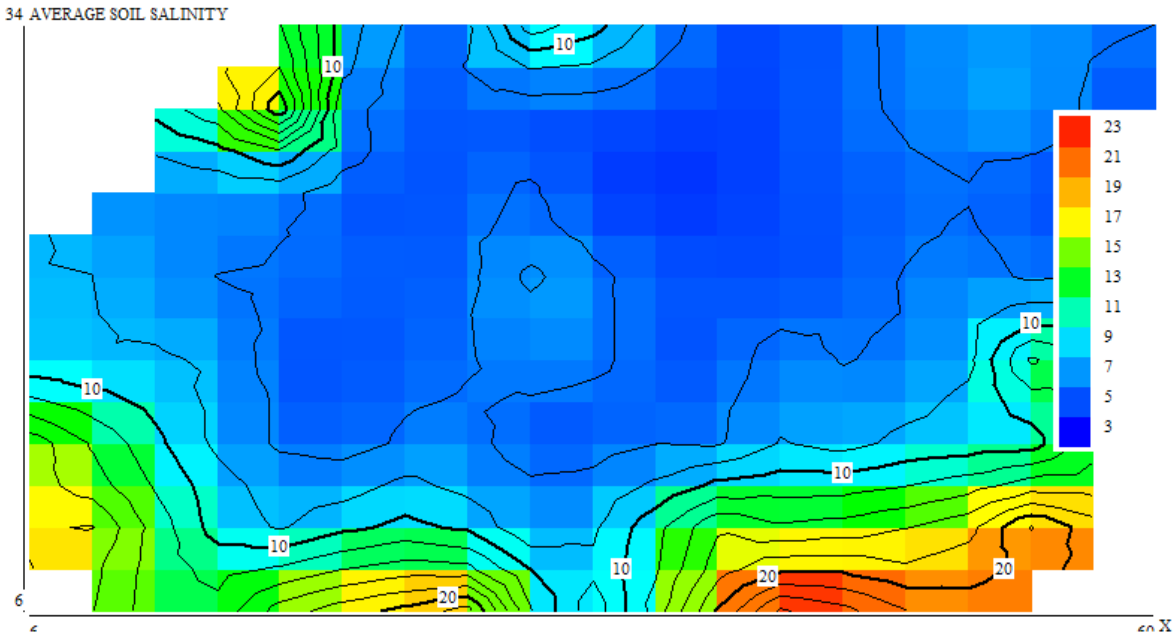
*In the automatic procedure (*figure 17*) the number of classes is one less and the class limits are different.*

When activating the "Ready" button, the polygonal map of the average soil salinity according to these specifications will be revealed, see the picture placed on the next page.



This figure is like figure 17*, but via a manual specification procedure (previous figure) the map looks quite different, even though it relates to the same soil salinity, the same season and the same year.*

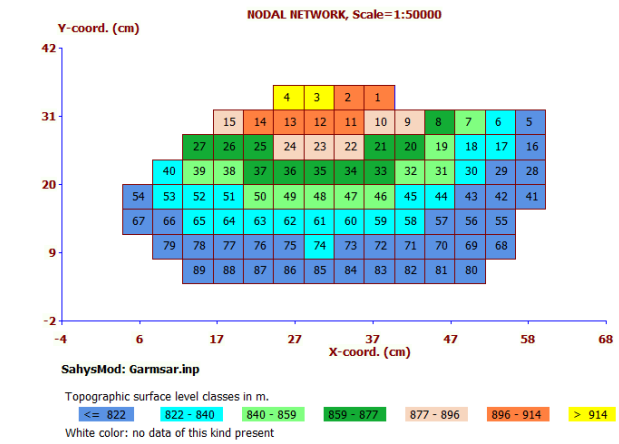
A map with soil salinity contours has been made with the free Quikgrid program and the result is seen in the following image.



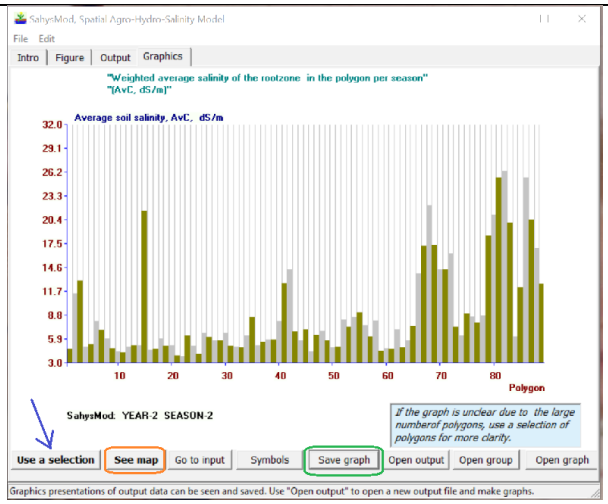
Contour lines of soil salinity with the same data as in the foregoing illustration. The map is made with the free Quikgrid program.

Appendix C. Relations between topographic level. soil salinity, depth of water table, capillary rise, and hydraulic conductivity

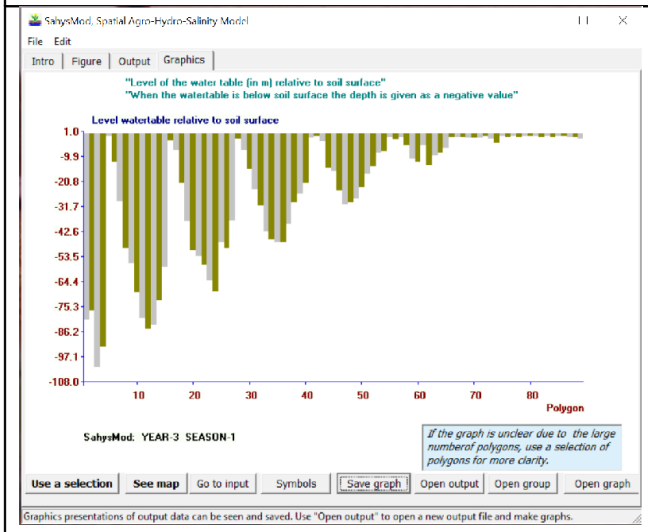
The figures in the table hereunder and on the next page cover the aspects of topography (level of the soil surface), average soil salinity, depth of the water table, capillary rise, and aquifer hydraulic conductivity. To interpret the relations between these magnitudes more easily, the corresponding print outs of these items (see *figure 12* for the "Save group" instruction) have been imported in an Excel work sheet (here the separation instruction has to be provided and in continuation the space instruction has to be given) and a graph was made with the topographic level of the soil surface on the horizontal X=axis and values of adjusted magnitude values on the Y-axis (see the very last figure below),



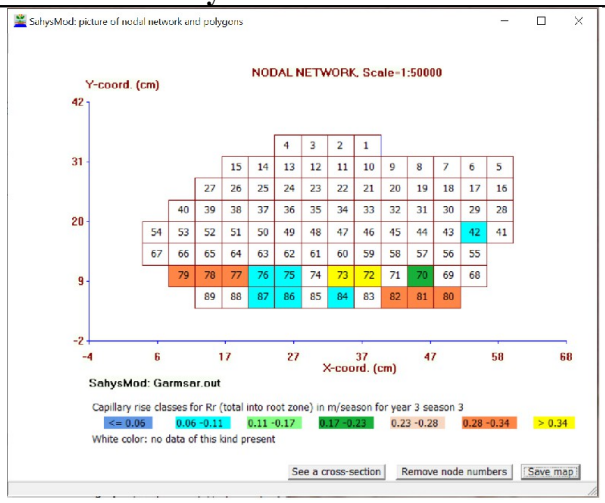
The topography



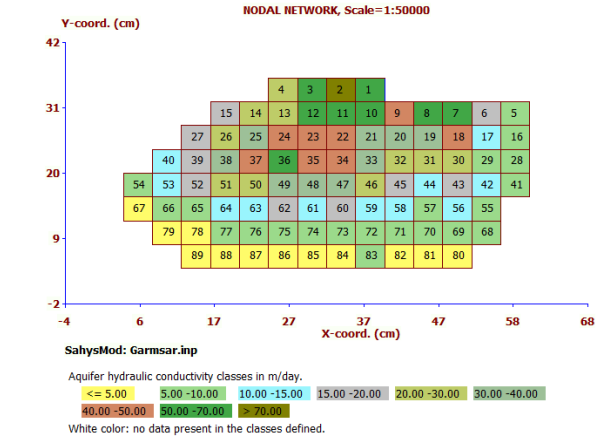
The soil salinity



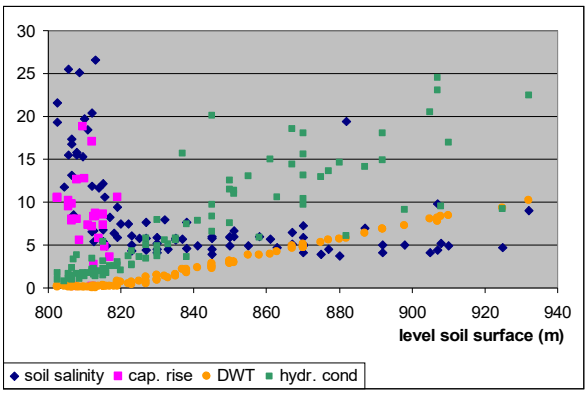
The depth of the water table



The capillary rise of water from the underground into the dry root zone

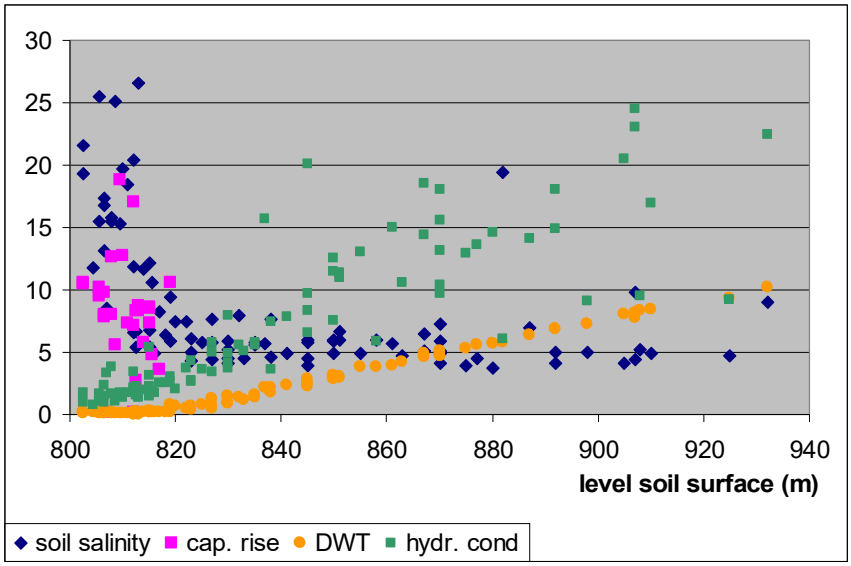


The hydraulic conductivity of the aquifer



The composition of the previous factors in an Excel graph.

The last graph is reproduced hereunder in a somewhat enlarged format for better visibility.



Legend: soil salinity in dS/m, cap. rise = capillary rise in cm/day, DWT = depth of the water table in units of 10 m, hydr. cond = hydraulic conductivity of the aquifer in units m/3 per day. The units have to be adjusted so that the can be plotted against the same Y-axis.

The conclusions that can be drawn are:

1. The capillary rise (purple) only occurs in the lower lying polygons with a level below 820 m.
2. Like the capillary rise, the soil salinity (dark blue) is highest in the lower lying polygons, especially those with a level below 820 m.
3. The soil salinity is correlated with the capillary rise.
4. In the higher lying polygons the soil salinity becomes more or less constant, around 5dS/m, which is tolerable by most crops.
5. Both the depth of the water table (orange) and the hydraulic conductivity of the aquifer (green) increase in the direction of the higher lying polygons. These three magnitudes are correlated, but the hydraulic conductivity has a large scatter in the higher lying polygons.