SPACSYS (v5.20)
Installation and operation manual

Developed by

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The model has been tested in Windows XP Professional with Service Pack 3, Windows 7 Professional and Windows 10 Education. To run the model, a database management system either MS SQL server (2008 R2 or over) or MySQL server 5.0 over must be installed in the machine or can be remotely accessed.

It was highly suggested change the language to English.

Citation for the manual:

Wu, L. (2017). SPACSYS (v5.20) - Installation and operation manual. Rothamsted Research. North Wyke, UK

Contents

Model installation

1. Software installation

From the folder where the installation package is stored, right click setup.exe to shoose ***run as administrator*** for software installation (highlighted in Figure 1). There may be a security issue to prevent from the installation to the machine. If it happened, please check the trouble shooter.

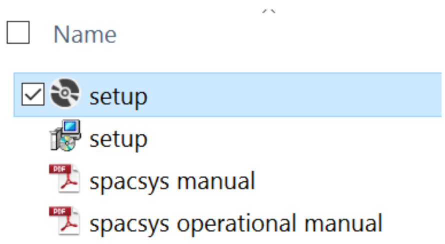


Figure 1 . Setup file structure of SPACSYS

The model has been tested in Windows XP Professional with Service Pack 3, Windows 7 Professional and Windows 10 Education either 32 or 64 bits. Run setup application in this package to install the model and follow the instructions to finish the installation. This setup requires Microsoft .NET Framework 4.6 over and will detect if the machine has been installed. If it is not installed, the setup application might automatically install it for you.

2. Create a data source (ODBC)

The SPACSYS model is linked to a database management system by an ODBC driver through configuring a data source. Before a link between DBMS and the model is set up, the data source has to be created by adding a user data source through the Administrative Tool of the Windows (Control Panel→ System and Security→ Administrative Tools→Data Source (ODBC)). For MySQL, the driver is “MySQL ODBC 5.1 Driver” and MS SQL is “SQL Server”.

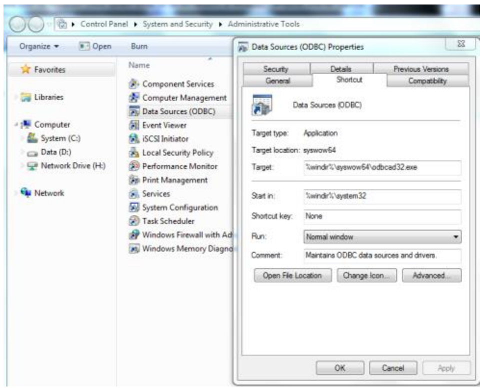


Figure 2. Change the version of the ODBC Administrator tool

On 64-bit versions of Windows 7, there might not all ODBC drivers visible. Usually only the SQL-Native Client and SQL-Server in the ODBC Data Source Administrators Windows are shown. To set up an ODBC data source, you must create the ODBC data source by using the ODBC Administrator tool in %windir%\SysWOW64\odbcad32.exe (Figure 2).

MS SQL server may have security issues. It should consult with system administrator if there is any problem to create a data source for MS SQL. Here is an example on how to create a data source for the SQL ODBC driver. After clicking the Add button in the ODBC windows and selecting the MySQL server driver, a child windows should pop up for information to be filled in (Figure 3). Any name can be given for Data Source Name. After the information is supplied, the system should tell if the configuration is successful or not by clicking the test button.

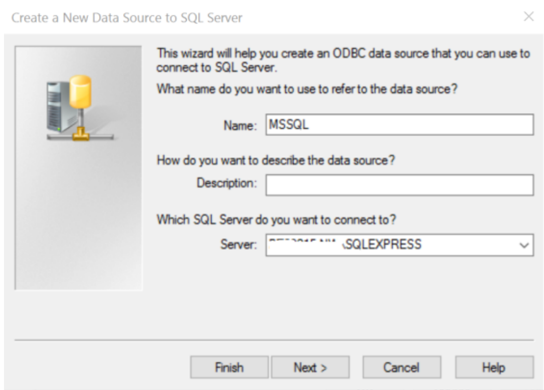


Figure 3 . Data source configuration for SQL driver

After a connection is set up, remember the data source name, user name and password. The information will be used to connect to the server when running the model.

3. Create a database

Either MySQL or MS SQL could create new databases through a third party program with friendly-user interfaces, e.g. MySQL-Front, MySQL workbench (both for MySQL) or SQL Server Management Studio Express (for MS SQL). Alternatively, the SPACSYS model itself could create databases with a model interface. When the program is opened, click Create a database in the connect menu (Figure 4). A new child windows will pop up, necessary information about ODBC connection will collect and the name of the new database (e.g. training) will be asked to be keyed in (Figure 5). From there, a new and user-defined database can be created. Users can create as many as they can following the same procedure.

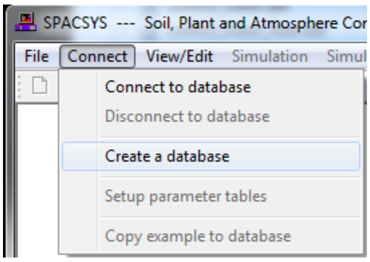


Figure 5 . The child windows to create a new database

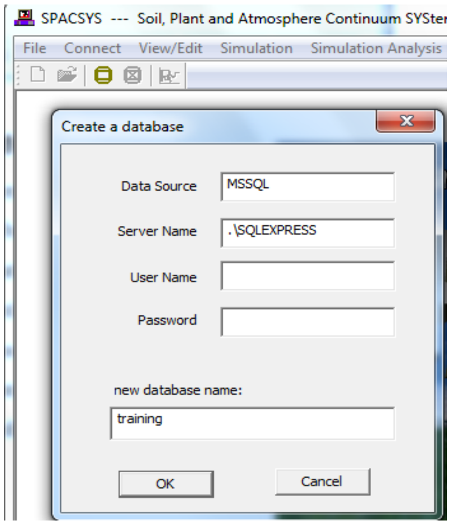


Figure 4 . Interface to create a database in the model

Model setup

After installation, essential information included in the model should be stored in a database (or databases) through the function of "setup parameter tables" in order to operate the model properly.

1. Connect to a database

Apart from the function of "create a new database", all other operations from the model have to be executed after database(s) connected successfully. Up to two databases can be connected simultaneously. It that case, users are given flexibility to organize data structure. Usually, those data with fewer changes and applicable to various simulation scenarios (e.g. weather data, soil properties and plant parameters, called data-database thereafter) could be stored in a database and those related to simulations and outputs could be stored in another database (e.g. working database). To connect to database, click the function of "Connect to database" under the Connect in the menu bar. The child windows, Connect to a data source, will pop up, shown in Figure 6. As an example in Figure 6, the database training_data was chosen to store essential information while the database training_work for parameter values of simulations and results. If only one database is used, just select the database for both the data database and the working database. After all of the information was filled in, to click the OK button in the child windows for connection. If the connection is successful, the message to indicate which working database is connected will be shown in the status bar (Figure 7).

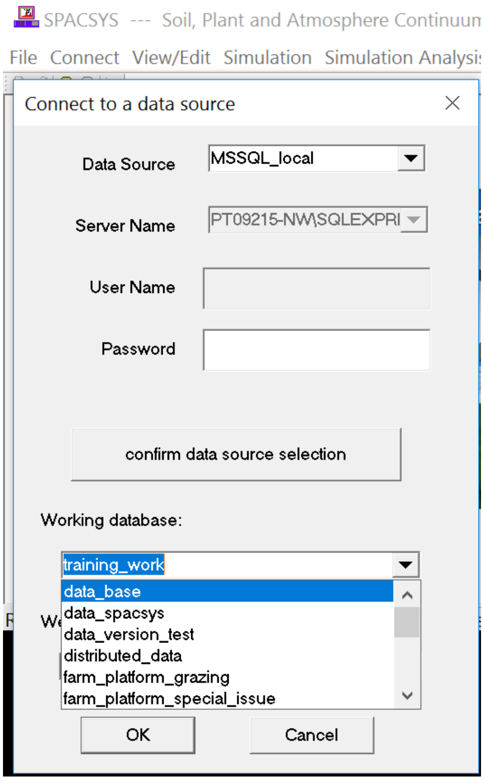


Figure 6. Interface to connect databases

Note: if another database is to be connected after the connection, the current selected database(s) should be disconnected first by the function of "Disconnect database" under connect in the menu bar and then the procedure for connecting database should be followed.

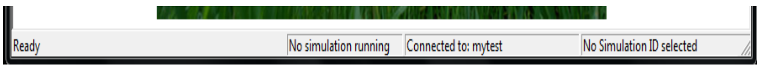


Figure 7. Indication of the working database connected

2. Setup a database with model configuration

When the model indicates the connection is setup successfully, the primary settings for the model can be copied into the working database and/or data database by clicking the Setup parameter tables item in the menu of the model (Connect-> Setup parameter tables), shown in Figure 8. After the execution, all existing parameter values in the database will be destroyed. Because the execution is irreversible, there is a warning box pupping up after clicking the function in the menu bar (Figure 9). If this is a right choice, then click the Yes button within the warning windows.

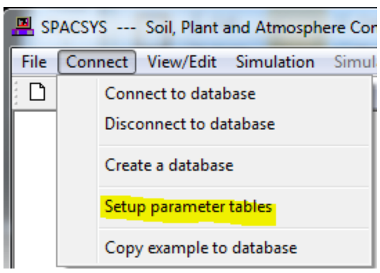


Figure 8. Location of setup parameter tables in the menu bar

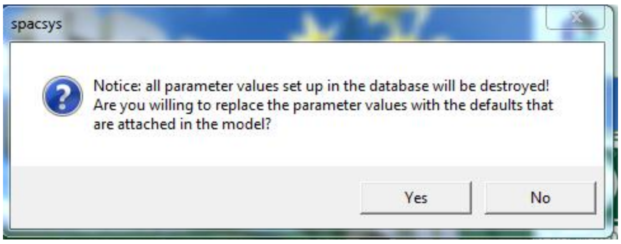


Figure 9. Warning message to execute the function of setup parameter tables

Warning: it is highly recommended to run this only once a database is created. Otherwise, all information stored in the database(s) would be lost.

3. Copy examples into created database

Supposing the database has been set up and the setup parameter tables has been executed successfully, the examples can be copied into the working database by clicking the copy example to database menu item under connect menu (Connect-> copy example to database), shown in Figure 10.

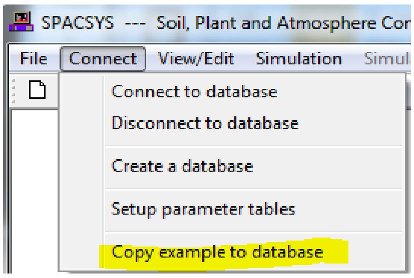


Figure 10. Location of copy sample to database in the menu bar

Basic operations of inerface

To distinguish configurations and outputs for various scenarios, a unique simulation ID must be assigned to a specific simulation. There may be identical parameter values between simulation IDs. However, the simulation ID cannot be shared between simulation settings. An existing simulation setting can be copied into a new simulation ID or deleted. Any existing simulation setting can be viewed/edited through the interface of the software.

1. Copy a simulation

To copy a simulation setting to a new one, just click the Copy a simulation under the file in the menu bar. A small child windows pops up (Figure 11). To click relevant items and fill in the information required in it following the instruction shown in the message box. A source simulation identification shown in the listbox within the windows is double clicked and the name of new simulation can be typed in the text box, then the button selected is clicked. The new simulation will be added into the working database. Users can select the new simulation from the child windows by clicking File in the menu and then Open to edit it.

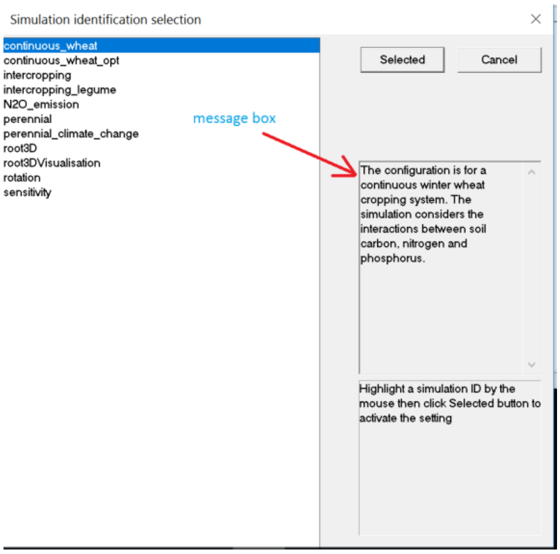


Figure 11. Interface to copy/delete a simulation

2. Delete a simulation

Similar to copying a simulation, but click the Delete a simulation function and then following the instruction to delete a simulation (including both the settings and simulation results if existed, Figure 11). All information related to the simulation, including simulation results will be physically removed from the working database. Although a simulation can be removed manually from the working database, it is time consuming to delete all relevant records from each tables involved. It is worth using the interface of the model to carry out the job.

3. Create a new simulation

There are two ways to create a new simulation: using new function under the File in the menu bar or copying an existing simulation into a new one. The first method will create a simulation from a scratch, and the latter is an easier way to generate a new simulation.

If creating a simulation from scratch, a parameter edition windows will appear after click New under File menu. Some information must be collected before the Save or Continue to view/edit parameters button is clicked. The information includes Simulation ID, driving variable table, field ID and soil property table. Other information can be added later. The settings of control variables in the datagrid windows will affect other settings. More information about this can be found in the following section (View/edit a simulation).

4. Compare two settings

The function allows the user to compare the differences of the settings including parameters and input variables between two simulation IDs. Therefore, the user can determine if the compared paire are identical or what differences are. When click the function the File menu, a new child windows pops up (Figure 12). After two simulation IDs selected and click the Compare button, all variables that are different in the two simulation IDs will display immediately in the message box. The compared result can be saved in a txt format file by clicking the Save compared result button.

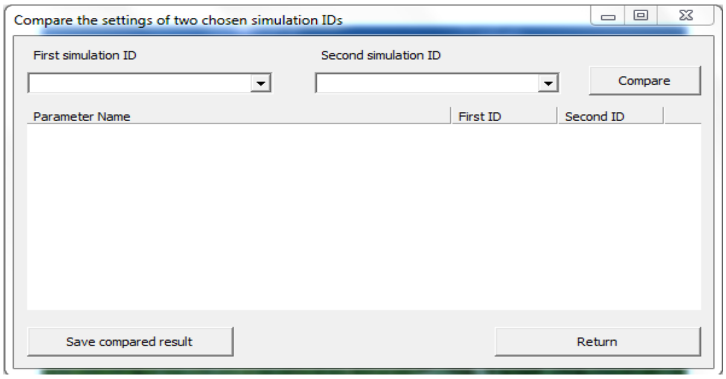


Figure 12. The interface of comparing variable values for two simulation IDs

5. Rename a simulation

A simulation ID can be renamed. The operional procedure is similar to copy a simulation. After it, all tables related to the simulation ID including simulation results are given the new ID.

6. Delete simulations

The function is the same as the delete a simulation. This function allows the user to delete multiple simulation IDS once. By doing this, press the Ctrl button and click the IDs that are intended to be deleted.

7. View/edit a simulation

To view/edit a simulation, the simulation ID must be chosen from the simulation identification list. After a simulation ID was chosen, click Edit parameters under the Edit/review menu (Figure 13). There is a real-time help for each parameter/variable when the cursor is put on the parameter location. To get help on a control variable or a parameter located in the datagrid (table-alike), just put the cursor onto the row (not in the column of value) where the variable/parameter is shown and double click. To make sure the changes in the datagrid in effect, click anywhere else after a change to a control/parameter is made. The practice is applied to all datagrids through data edition.

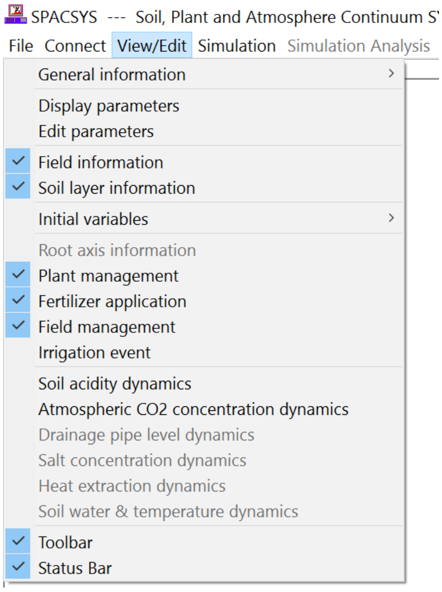


Figure 13. Procedures to view/edit parameters for a selected simulation

7.1 View/edit parameters

If only the parameters configured are viewed for the chosen simulation ID, the function of Display parameters shown in item 2 in Figure 13 can be clicked. If some parameter values would be modified, the function of edit parameters can be executed. A child Windows pops up (Figure 14). Users can change any information but the simulation ID from popped windows. There are some information within three coloured rectangulars should be noted in Figure 14.

Within the green rectangular, there are options to be chosen for which elements would be simulated for the simulation. When double clicking the head of a row on the datagrid, a brief explanation about the control variable will be shown.

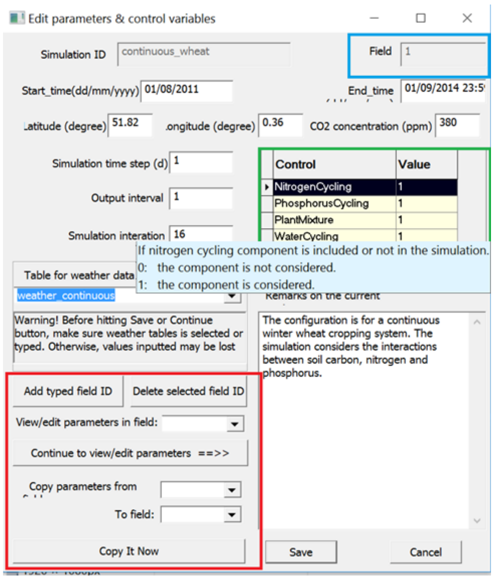


Figure 15. Editing parameters

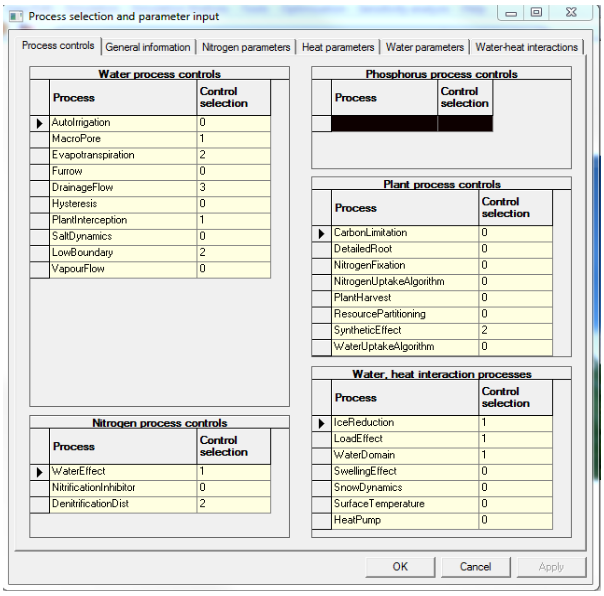


Figure 14. select processes and edit parameter values

Within the blue rectangular, there is a field number that cannot be changed manually for the simulation ID. In a simulation, there could be multiple fields to be simultanously modelled. However, same weather dataset (determined by the table of weather data) is shared for all the fields with the simulation ID. For each field, there could be unique soil properties (represented in a soil property table), parameter values, field and crop management practices (e.g. cultivar, sowing date). In this example, there is only one field. The field ID can be any combination of letters (insensitive to capitials) and numbers. It is highly recommended the ID starts with a letter.

The information and configurations from one field can be copied into other fields, with the actions within the red rectangular. In that case, it would be easier to configure the fields by editing individual field. Each time the parameter values from a single field can be viewed and edited through selecting the field number at the top of the red rectangular.

After a field ID is selected from the drop-down list and click the "continue to view/edit parameters ==>" button with the red rectangular in Figure 14, the child windows of process selection and parameter input in which there are six tabs pops up (Figure 15). **It is highly recommended to determine all control variables in the process controls tabs first.** The values of the control variables affect which parameters in the rest of tabs and if extra information are required. All controls in the process control tab should have an effective value. Otherwise, those without any valid value will be treated as zero when running the simulation. Again by double clicking the head of a row in a datagrid, a brief help text will appear. The range of the value for a control can be found from the real-time help. All parameters appeared in other tabs should have a value except some of them in the tab of Nitrogen Parameter. Under the tab, parameters of dissolved fraction from fresh organic matter, humus fraction from fresh OM and potential decomposition rate of fresh OM can leave empty depending on how many fresh organic matter pools are defined in the configuration. For example, assuming that only one type of fresh organic matter pool is applied, then those three parameters with _1 as an affix should have values and others are empty.

Detailed information on each control variable or parameter can be found from the technical manual. After all changes have been made, click the OK button in the window, which closes it and return to it parental windows (Figure 14). If there is any change has been made, then click the Save button. Otherwise, click the Cancel button.

7.2 View/edit managements

After parameters and process controls was determined, relevant management or auxiliary information can be added or edited. Editing the information should be done after editing parameters as it is affected by processes involved (selection of processes controls in above session).

Which information is required for the simulation can be found which functions are ready to be clicked under the View/Edit in the menu bar (item 2 in Figure 13). In this example shown in the figure, some information has been stored in the tables in the database (indicated as checked item). Those greyed items mean the information would not be expected for the simulation. Although some items are activated in the example (e.g. irrigation, initial plant status), there might be unnecessary for the simulation. For example, no irrigation is available for the simulation. There is no plant/crop growing in the field at the time when it starts to simulate. As rule of thumb, the following information should be presented in each simulation: field information, soil layer information, initial water, heat conditions and initial pool sizes of carbon and nitrogen.

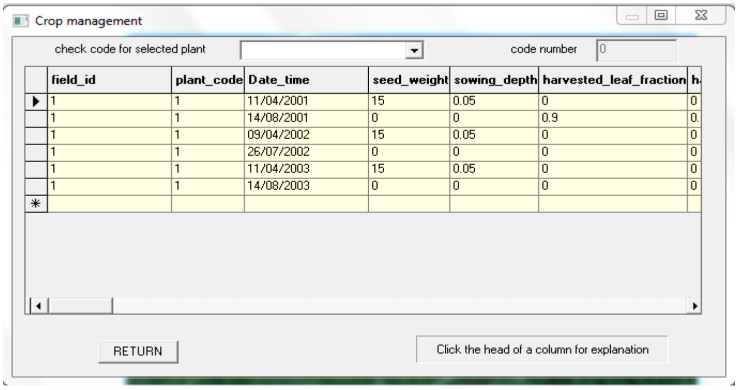


Figure 16. Window of crop management

When a table was edited, to click the head of either a row or a column, there should appear a brief explanation on the selected variable.

As an example, here describe how to edit/add plant/crop management. After databases were connected and a simulation ID was chosen, click the function of Plant management under View/edit in the menu bar. A child windows pops up shown in Figure 16.

1) If a record was to be deleted, click the head of the row where the record was located and press Delete from the keyboard.

2) If a parameter value needs to be edited/added, just put the mouse pointer to the cell and change it and **then get the pointer to somewhere else for update.**

3) If a new record needs to be added, first to type the field ID to indicate which field the information is applied to, then to determine which plant/cultivar is simulated for the specific event, and then date & time and parameter values for the rest of columns in the datagrid. To determine the plant code of the plant/cultivar, select the plant/cultivar from the drop-down list at the top of the child windows, the code would appear in the text windows at the top-right corner of the child windows.

After the information was ready, then click the RETURN button to get all information written into relevant tables.

Simulation and display results

1. Run a simulation

If all information for a simulation ID has been collected, it is possible to run the simulation. To do so, click the function of Run a simulation under simulation in the menu bar after a simulation was selected (Figure 17). If a simulation is finished, the message to indicate that it has run successfully would be shown in the status bar (shown as at the bottom of Figure 17).

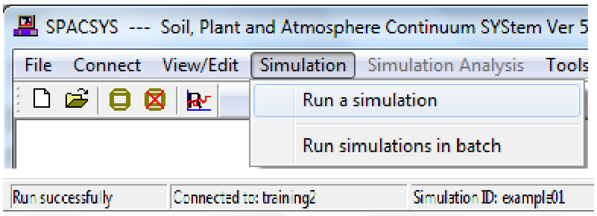


Figure 17. Function of run a simulation

There may be a chance to run number of simulations. If running them one by one, users have to monitor the progress of simulations. Running simulations in a batch may be a better choice. To use this function, all simulations should be configured in advance. Write all simulation identifications into a text file and make sure that the spellings of the identifications are the exact same as those stored in the tables. After databases are connected, click Run simulations in batch function under simulation of the menu (Simulation->Run simulations in batch).

2. Display simulation results

If a simulation has been run and results stored in the database, then the item of simulation analysis in the menu bar would be activated (Figure 18). Some simpler analysis can be carried out through the model interface. After a simulation configuration is run successfully, Users can browse various kinds of analysis for simulation results by clicking relevant functions in the Analysis menu. The displayed results on a screen can be written into a text file that can be opened by MS Excel for further analysis.

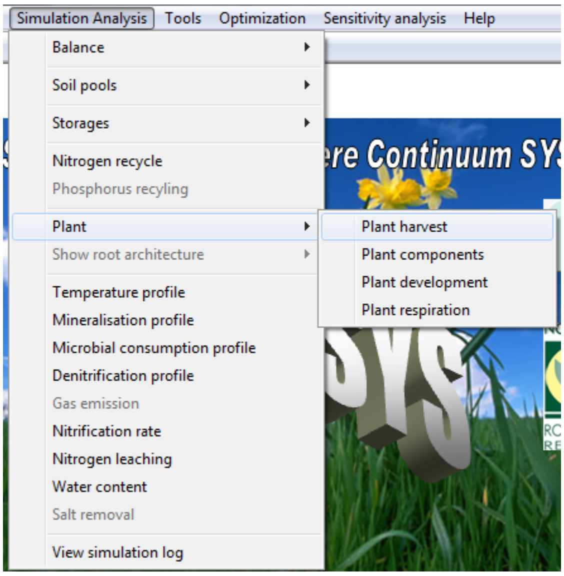


Figure 18. Functions of showing simulation results

3. Copy outputs into text files

All outputs from a simulation are stored in tables in the working database. Because DBMS may lack of flexibility in data analysis, it would be better to export the outputs into text files. From there, other programs could be used for further analysis or creating graphs. There are six files in total that could be produced. Users have to create these files one by one. The functions to export the outputs can be found under the tools menu.

4. Change time windows for displaying/exporting outputs

Occasionally, users may be interested in simulation results in a particular simulation period. Interface can change the time windows to meet the requirement. To do so, click Change period function in the Tools menu.

Operations on essential data

There are three types of data stored in the data-database (training_data): weather, soil properties and crop/plant parameters. All of the information can be manipulated (create, modify and delete) through the model by clicking a relevant menu function (Figure 19).

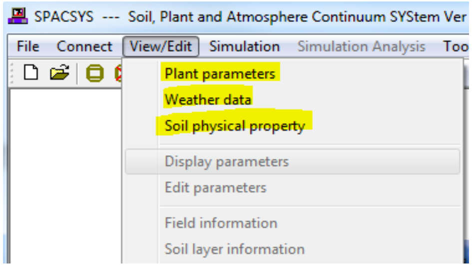


Figure 19. Manipulation of essential data stored in a data-database

1. Weather data

There are several ways to put weather data into a table: 1) directly type in data through the interface of the weather data input; 2) import data from a text file through the interface and 3) copy data from an ODBC table or files that the DBMS accepts. There is a table named climatesites in the data-database to log the tables (with table name) that weather data has been stored in the data database. To name a weather table, a thumb rule should be followed: it cannot be named starting with any simulation ID. The consequence violating the rule is that the weather table the name started with a simulation ID will be deleted when running a simulation with the ID later.

1.1 Directly type in data

Theoretically, all weather data can be keyed in with the interface of the weather data input. To do so, connect database(s) first and then click weather data under View/Edit in the menu bar, and a new child windows will pop up (Figure 20). Typing the name for the weather data in the text window of drop down list under "Select a profile". In the example, the name was weather_example1. After the name was determined, click the Create button. If nothing happened, it indicated that the name has been in the list. In that case, click the Edit button. Now it is ready to key in the weather data in the datagrid (the yellow table in the middle in Figure 20). Click the head of each column once, a short help text will display. After one record is finished, just click symbol * in the front of the record, a new empty record will appear for next record. Click the OK button to finish data input. Usually, the size of weather data is huge. It is unwise to use this method for weather data. The next option should be considered.

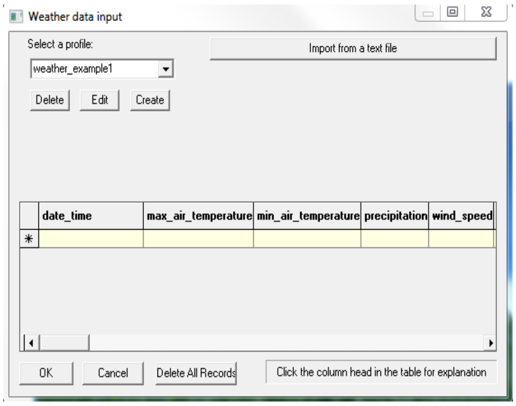


Figure 20. Interface of weather data input

1.2 Import data from a text file

Daily weather data can be imported with the program, which works with an ASCII formatted plain text file. For the text format file, records are arranged with lines. Each line represents a record. There is a comma to separate variables.

The order of variables should be date and time (yyyy-mm-dd hh:mm, the format for date and time is the same throughout the model input), daily maximum air temperature (°C), daily minimum air temperature (°C), precipitation (mm), wind speed (m/s), relative humidity (%), sunshine hours (hrs), global radiation (J/m^2/day) and net radiation (J/m^2/day).

Maximum and minimum temperatures, wind speed and precipitation must be presented. If global radiation is presented, sunshine hours might be ignored. Otherwise, sunshine hours should be presented so that both global radiation and net radiation will be estimated in the model. If neither global radiation nor net radiation is presented, a negative value for global radiation and the value of 1.0e+10 for net radiation should occupy the position. If either relative humidity or sunshine hours is unavailable, then a negative value must be set in the position.

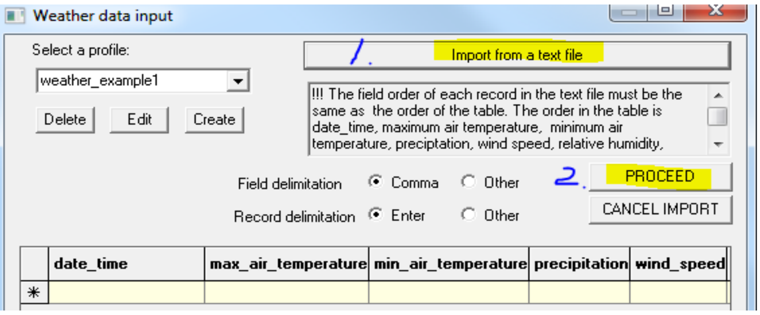


Figure 21. Interface to import weather data through a text file

The following lines are an example with the ASCII format:

2006-01-01 09:00, -3.9, -18.6, 0.0, 2.3, 69.0, 7.4, -99.0, 1.0e+10

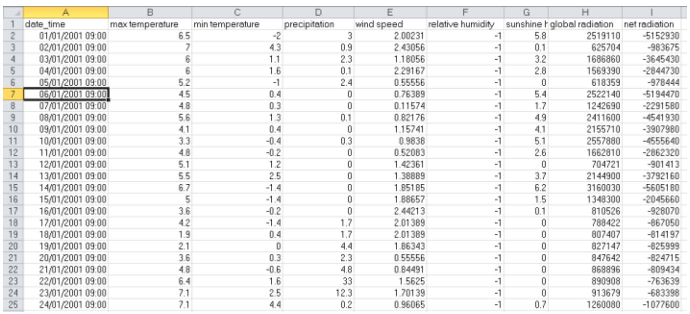
2006/01/02 09:00, -7.7, -18.4, 2.5, 1.0, 75.0, 0.0, -99.0, 1.0e+10

The dataset above shows that solar radiation and net radiation are not available.

After the text file was organised, the data can be imported by clicking the button of Import from a text file within the interface mentioned in section Directly type in data. Following the instruction, the data stored in the text file can be transferred to the table with the typed name by clicking the Proceed button (Figure 21).

1.3 Import weather data with a DBMS

The procedure to import weather data from a file into a database through a DBMS will depend on which third party program is used. Here using MySQL-Front to import data from a Microsoft Excel file as an example. First of all, a weather table is named using the same procedure described from previous sections (e.g. weather_data).



	A	B	C	D	E	F	G	H	I
1	date_time	max temperature	min temperature	precipitation	wind speed	relative humidity	sunshine h	global radiation	net radiation
2	01/01/2001 09:00	6.5	-2	3	2.00231	-1	5.8	2519110	-5152930
3	02/01/2001 09:00	7	4.3	0.9	2.43056	-1	0.1	625704	-983675
4	03/01/2001 09:00	6	1.1	2.3	1.18056	-1	3.2	1686860	-3645430
5	04/01/2001 09:00	6	1.6	0.1	2.29167	-1	2.8	1569390	-2844730
6	05/01/2001 09:00	5.2	-1	2.4	0.55556	-1	0	618359	-978444
7	06/01/2001 09:00	4.5	0.4	0	0.76389	-1	5.4	2522140	-5194470
8	07/01/2001 09:00	4.8	0.3	0	0.11574	-1	1.7	1242690	-2291580
9	08/01/2001 09:00	5.6	1.3	0.1	0.82176	-1	4.9	2411600	-4541930
10	09/01/2001 09:00	4.1	0.4	0	1.15741	-1	4.1	2155710	-3907980
11	10/01/2001 09:00	3.3	-0.4	0.3	0.9838	-1	5.1	2557880	-4555640
12	11/01/2001 09:00	4.8	-0.2	0	0.52083	-1	2.6	1662810	-2862320
13	12/01/2001 09:00	5.1	1.2	0	1.42361	-1	0	704721	-901413
14	13/01/2001 09:00	5.5	2.5	0	1.38889	-1	3.7	2144900	-3792160
15	14/01/2001 09:00	6.7	-1.4	0	1.85185	-1	6.2	3160030	-5605180
16	15/01/2001 09:00	5	-1.4	0	1.88657	-1	1.5	1348300	-2045660
17	16/01/2001 09:00	3.6	-0.2	0	2.44213	-1	0.1	810526	-928070
18	17/01/2001 09:00	4.2	-1.4	1.7	2.01389	-1	0	788422	-867050
19	18/01/2001 09:00	1.9	0.4	1.7	2.01389	-1	0	807407	-814197
20	19/01/2001 09:00	2.1	0	4.4	1.86343	-1	0	827147	-825999
21	20/01/2001 09:00	3.6	0.3	2.3	0.55556	-1	0	847642	-824715
22	21/01/2001 09:00	4.8	-0.6	4.8	0.84491	-1	0	868896	-809434
23	22/01/2001 09:00	6.4	1.6	33	1.5625	-1	0	890908	-763639
24	23/01/2001 09:00	7.1	2.5	12.3	1.70139	-1	0	913679	-683398
25	24/01/2001 09:00	7.1	4.4	0.2	0.96065	-1	0.7	1260080	-1077600

Figure 23. Example of MS Excel file to store weather

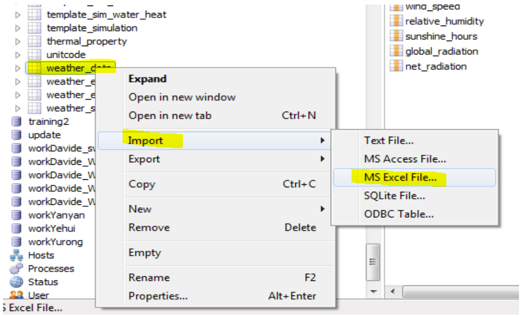


Figure 22. MySQL interface to import weather data from an excel file into a table

Weather data was edited through Excel and stored in a file (e.g. weather sample.xls, 97-2003 version only, Figure 22). With MySQL-front, expand the database where the named weather table is located (e.g. training1), right click the table weather_data. From the popped menu, highlight Import and choose MS Excel file (Figure 23). Following the instruction, the data should be imported into the table.

A logged weather table can be deleted through the interface of the weather data input (Figure 20). To highlight the table name that is to be deleted from the drop-down list then click the delete button. The table should be deleted and logged information for the table will be removed from the log table.

A single record or all records within a weather data table can be deleted with the interface. To highlight the table name that is to be edited from the drop-down list and then click the edit button. All records will appear in the datagrid. To delete all records, just click the Delete All Records button. To delete a single record, click the head of the record to be deleted and then press the Delete button from the keyboard.

2. Dynamics of soil water and temperature

In case, soil water movement and energy transformation does not include in a simulation, a table representing the dynamics of soil water and temperature must be presented in order to simulate other components, i.e. soil carbon, nitrogen, phosphorus, salinity and plant growth and development. The number of the fields in the table depends on soil layer number to be simulated. The fields in the table must be:

date_time (dd/mm/yyyy hh:mm),

water_added_to_soil_surface (mm/day),

water_infiltration_to_soil (mm/day),

water_loss_rate_through_bottom (mm/day),

surface_runoff_rate (mm/day),

surface_water_coverage_fraction (-),

water_equivalent_in_snow (mm),

soil_temperature_layer_1, …, soil_temperature_layer_n (°C),

water_content_layer_1, …, water_content_layer_n (vol%),

water_tension_layer_1, …, water_tension_layer_n (cm),

water_storage_in_high_domain_layer_1, …, water_storage_in_high_domain_layer_n (mm),

water_flow_between_soil_layer_1, …, water_flow_between_soil_layer_n (mm),

ground_water_flow_layer_1, …, ground_water_flow_layer_n (mm),

macro_pore_water_flow_layer_1, …, macrop_pore_water_flow_layer_n (mm) (n is the soil layer number).

The field name must be defined the same as above.

3. Soil properties

The way to manipulate soil physical properties in a site is the same as the weather data. But there is no option to import the data from an ASCII format file into a table directly. Users should decide whether the Brook & Corey equation or the van Genuchten equation for water retention curve (for detail, look up the technical manual included in the software package) is used by clicking a radio button in the child windows (Figure 24). Through the windows of soil physical properties, any soil profile listed in the profile drop-down list can be deleted, edited by clicking relevant buttons. New soil profiles can also be created. If a new soil profile is created, a thumb rule for naming the profile is that it cannot be named starting with any simulation ID. The consequence violating the rule is that the soil profile that its name starts with a simulation ID might be deleted when running a simulation with the ID later.

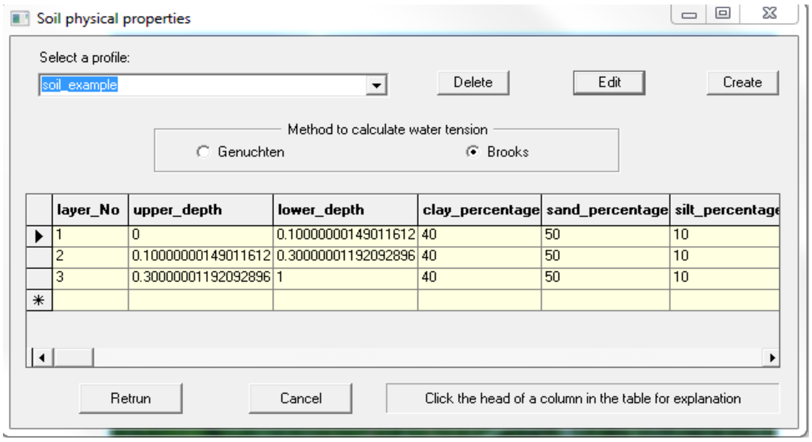


Figure 24. Interface to manipulate soil properties

Soil physical properties can be configured with soil layers (soil horizons). **The number of layers in a profile and the thickness of each layer that are deterimind by measured data are not necessary to be identical to the setting of soil layers in simulation configurations**. Each layer should include the following variables: upper boundary the soil layer (to the soil surface, cm), lower boundary of the soil layer (to the soil surface, cm), clay percentage (%), sand percentage (%), silt percentage (%), dry soil bulk density (g/cm^3), residual water content (vol%), saturated water content (vol%), field capacity (%), water content at wilting point (vol%), saturated conductivity, excluding contribution from the macro pores (mm/day), saturated conductivity including the contribution from macro pores (mm/day), pore size distribution index (-), air entry pressure (cm water) and pH value (-). If the Brooks and Corey's equation is used, the values of water content for macro pore volume (vol%) and tortuosity coefficient (-)in the equation should be included. Click the head of each column once, a short help text will display.

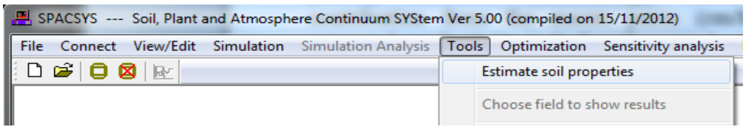


Figure 26. Interface for estimating soil properties with soil texture

It would be difficult to gain all data for soil physical properties for a simulated site. It is possible to estimate some of them with soil texture that is common known from the software. To do this, the function of Estimate soil properties under tools in the menu bar is clicked after databases were connected (Figure 25). A child Windows will pop up. Then a table name for the soil properties is asked to be typed in or chosen from existing tables. After all information required in the datagrid is filled in, click the Estimate button with the child windows (Figure 26).

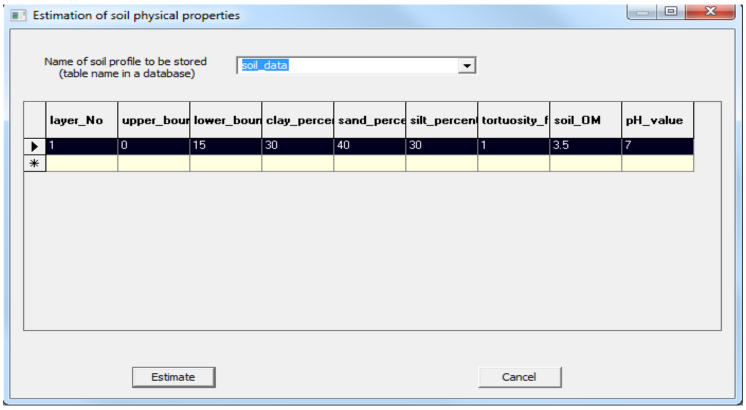


Figure 25. The child Windows for information used to estimate soil properties

There is a table named soilprofile to log any soil profile (with table name) that soil properties have been stored in the data database.

4. Plant/crop parameters

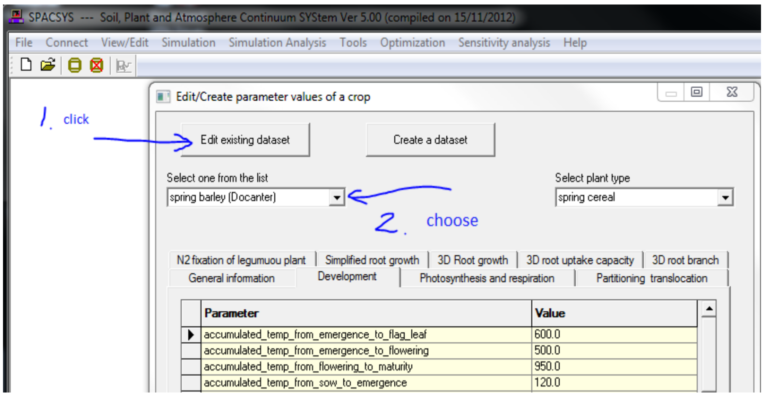


Figure 27. Procedures to edit existing data

Some plants/crops have been parameterized and their information is stored in the tables using the names started with "plant_" in the data-database (training_data). Individual tables are linked with a plant_code as a primary key. The values for a crop/cultivar stored in the database can be modified through the interface shown in Figure 27. Put the mouse pointer to the cell in which the value of a parameter is to be modified and input the value, **then get the pointer to somewhere else (this procedure is applied to the values shown in any datagrid)**. Now it could be noted that the value in the cell has been changed. After the changes have been made, click the OK button in the child windows. Click the head of each row once, a short help text will display for the parameter. More detailed information about each parameter can be found from the technical manual.

If a new variety/cultivar is to be created, the following procedures could be applied (Figure 28) after the databases were connected and the function of plant parameters under the view/edit in the menu bar was clicked:

1. click the create a dataset button in the child Windows;
2. choose an existing crop/cultivar similar to the new one from the drop-down list;
3. Type the name of the new crop/cultivar;
4. Change plant type if required from the drop-down list of plant type;
5. If all information provided is correct, then click the confirm name entry button to add the dataset to the plant parameter tables.

If nothing wrong with it, then click the OK button to close the child windows.

To view/edit parameter values of the newly created dataset, just following the procedure shown on editing existed dataset above.

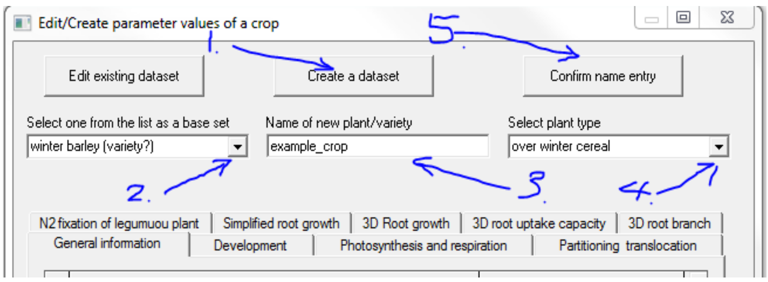


Figure 28. procedures to parameterize a new crop/cultivar

Information preparation for a simulation

A simulation may need further information to simulate an event which stores in separate tables in the working database. Whether it presents or not depends on simulated processes. When a simulation is selected from a simulation ID drawdown box, relevant tables in the menu will be activated. **It is highly recommended that parameter configurations be made before any tables mentioned in this appendix are worked on.**

1. Order to prepare information

If a simulation is created, then following the procedures described in Create a new simulation of Basic operations of interface. To modify an existing simulation configuration:

a) Determine which components will be modelled with the simulation ID, shown in the green rectangular box in Figure 14;

b) Determine processes to be included in the simulation shown in Figure 15 for each field;

c) Parameterise those in each tab in Figure 15. After this, click OK and then Save in Figure 14;

d) Provide extra information for each field, described in Configuring a simulation for multiple fields later;

e) Provide information on soil thickness each soil layer in each field, shown in Figure 29;

f) Any information included in this section can be keyed in with any order.

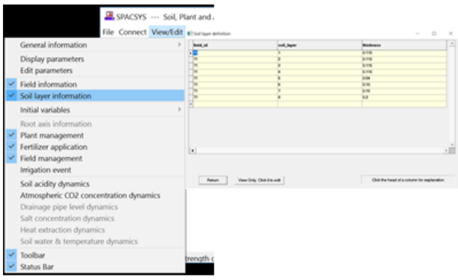


Figure 29. Input soil thickness

2. Soil thickness

The information about soil thickness must be presented for a simulation identification for running it. Thickness (m) for each soil layer is recorded in the sim_soilayer table for the specific simulation identification for each of simulated field. The number of the layers here for each field is equal to the number of soil layers filled in the field information function. Soil type number and maximum soil strength may be included in the table if a 3D root system is simulated.

3. Plant management

The table is used to manipulate the dates of plant sowing and/or harvest (cutting). Therefore, it will be activated if plant growth and development is simulated. Each event occupies one record. If plant is sown on a day, the information for the record is: seeds weight (g/m^2) and sowing depth (m), and leaving rest of the fields in the record empty. If the event is for harvest, the following information is required: the fraction of leaves that is removed from leaf dry weight; the fraction of stem that is removed from stem dry weight; the fraction of leaves that are still alive after harvest/cut in stubble; the fraction of stems that are still alive after harvest/cut in stubble and the fraction of roots that are still alive after harvest/cut from root dry weight.

A sowing date of a selected species can be determined by the model. If doing so, the sowing date in the field management table should be identified as “01/01/xxxx 23:00:00” where xxxx is the year of the simulation. If a simulation involves more than one sowing dates in a year, i.e. multiple cropping systems, sowing dates of species should be shown in the field management table as “01/01/xxxx 23:00:00”, “01/01/xxxx 23:01:00”, “01/01/xxxx 23:02:00”, etc. The sequence of species sown in a field is distinguished by minutes. It is assumed that all field activities should be carried out during day hours. The 23 hour was used as special means.

The sum of removed leaf fraction and alive leaf fraction in stubble should less than or equal to the unity. The same rule is applied to stems.

4. Field management

The field management table is used to service for the records of field tillage or cultivation. Each record represents one event that indicates with ploughing/cultivation depth (m). If there is no such an event occurred during the simulation, no any action should be taken.

If tillage is taken during the simulation, all remaining living leaves and stems, roots down to the depth given by the parameter in the table, and all above ground residues are evenly included in the litter pool down to the depth. The roots below the ploughing depth are incorporated in the corresponding litter pools.

Agricultural activities in the field will affect soil physical properties. After a period of disturbance, the properties might return back to the original values. Liu et al. (2014) showed that the period could last about 50 days in silt loam and sandy loam soils. Based on the data in the paper, a general equation considering the disturbance period and soil depth was derived:

$$DB_{t,d} = [(0.0036 + 0.008d)t + 0.8435d + 0.108]DB_o \tag{1}$$

where $DB_{t,d}$ is the soil bulk density on day t since a disturbance event at depth d; t is the days since a disturbance occurred, d is the soil depth (cm) and DB_o is the original value of soil bulk density at the soil depth.

5. Fertiliser application

There two kinds of external nitrogen suppliers: commercial fertiliser and manure/slurry/litter. Commercial fertiliser N consists of two parts: ammonium and nitrate. However, commercial fertiliser P could have more complex composition on P forms. Manure/slurry/litter is split up three parts: inorganic N/P, fresh organic matter and soluble organic matter. If there is no fertiliser application during the simulation, no any action should be taken.

There are different kinds of manures; here six kinds have been distinguished based on their nitrogen, fresh organic matter and soluble organic matter contents, C:N ratio, etc.

Each event should have the following information included: type of fertiliser, application method, application depth (m), amount of N or P application, dissolved carbon content, carbon content in the solid part, the fraction of soluble N, the fraction of ammonium form, the fraction of nitrate form, the fraction of stable organic form P, the fraction of active organic form P, the fraction in microbial biomass (if any), the fraction of mineral form P, the fraction of soluble P, the fraction of stable inorganic form P, the fraction of sorbed form P, and the fraction in precipitated form P. not all of the information has to be filled in depending on fertiliser types.

Nitrogen amount is total applied nitrogen (gN m^{-2}) on the day.

Phosphorus amount is total applied phosphorus (gN m^{-2}) on the day.

Different methods of application will affect its distribution in the soil and some nitrogen transforming processes, the methods are considered and classified three types: injection in a certain depth (1), surface splash (2) and uniformly mixed with soil within a certain depth (3).

Application depth is the depth to which the material is applied in the soil. Normal range is from 0.0 to 0.25m. If it is splashed, the depth is put zero.

6. Irrigation events

The table is used to record any irrigation events during a simulation. Each record represents one event that indicates with irrigation rate (mm/day). Only one event occurs within a day. If there is no irrigation application during the simulation, no any action should be taken.

7. Information on root axis appearance

The information is only required when a 3D root system is simulated. When the information is collected (the control variable *DetailedRoot* is set 1. The variable value can be changed in the Plant process control datagrid of Process Control tab in the Process selection and parameter input windows), users can get help for each parameter in the datagrid by double clicking the title of the column.

For simulation purpose, root axis has a broad definition used here. An axis can be either a seminal axis (appearing from the coleorhiza of the seed) or a nodal axis appearing from the coleoptile and stem nodes.

8. Dynamics of drainage pipe level

If the control variable, *DrainageFlow* is set to 2, there is an opportunity to change canal depth to the soil surface with time course. Although the table is named as drainage pipe level, it implies to a canal. The level of a drainage pipe should be fixed through the whole simulation period even beyond. The level between two readings is treated as a linear relationship with time. The information is optional even if the value of *DrainageFlow* is 2.

9. Dynamics of heat extraction

There are not active processes involved in salt dynamics automatically. If the control variable, *HeatPump*, is set 1, salt dynamics will be involved in the simulation. In this case, the information on salt concentration in water infiltrated into soil is required and stored in the table, salt_profile in the working database. The information is optional even if the value of *HeatPump* is 1.

10. Dynamics of salt concentration

There are not active processes involved in salt dynamics automatically. If the control variable, *SaltDynamics*, is set 1, salt dynamics will be involved in the simulation. In this case, the information on salt concentration in water infiltrated into soil is required and stored in the table, salt_profile in the working database. The information is optional even if the value of *SaltDynamics* is 1.

Initialisation of state variables

Most state variables need initial values at the start point for simulation. There are several tables to store initial values. It will depend on what processes will be involved in the simulation which tables are activated for editing.

1. Soil water, temperature and salt contents

If soil water cycling and heat transformation are included in a simulation, soil water content and temperature in each soil layer must be initialized. The number of soil layers is equal to the number of soil layers decided in the first windows in edit parameter function and stored in the parameter table, sim_simulation. If salt dynamics is considered in the simulation, salt concentration in each soil layer should be initialized as well.

2. Plant status

If a plant is involved and the start point of the simulation is in the middle of growing period, initial values of plant organs and growing stage, expressed in accumulated temperature since sowing are required. Further, root vertical distribution needs to be provided. To add the information into the table, using the following procedures:

Chose a simulation ID, and click View/Edit menu and then click Initial plant status or Initial plant root distribution.

3. Soil carbon contents

If nitrogen cycling is included in a simulation, carbon contents in the soil profile must be initialized. The number of soil layers is not necessarily equal to the number of soil layers decided in the first windows in edit parameter function and stored in the parameter table, sim_simulation.

The information about fresh organic matter pools depends on how many pools are defined in the system. The number of pools and their orders (1-6) defined here should be consistent with the number and orders did in the parameter configuration. For example, if two pools of fresh organic matter are defined in the configuration and ordered them as 1 and 2, carbon contents in soil layers of these pools should be initialized here.

4. Soil nitrogen contents

If nitrogen cycling is included in a simulation, nitrogen contents in the soil profile must be initialized. The number of soil layers is not necessarily equal to the number of soil layers decided in the first windows in edit parameter function and stored in the parameter table, sim_simulation.

If nitrogen denitrification rate is estimated with the simplified method, NO content and N_2O content should be ignored. The information about fresh organic matter pools depends on how many pools are defined in the system. The number of pools and their orders defined here should be consistent with the number and orders did in the parameter configuration. The rules for the definition of fresh organic matter are the same to initialising soil carbon contents.

5. Soil phosphorus contents

If phosphorus cycling is included in a simulation, phosphorus contents in the soil profile must be initialized. Similar to initializing carbon and nitrogen contents in the soil profile, the number of soil layers is not necessarily equal to the number of soil layers decided in the first windows in edit parameter function and stored in the parameter table, sim_simulation. Users may define the amount of each pool for all soil layers.

If there is no data available for the initialization, then soluble concentrations of 25 and 5 mg P kg^{-1} soil in the ploughing layer and non-ploughing layers could be considered, respectively. The concentration of phosphorus in the absorbed pool can be initialized as:

$$P_{sp} = P_{is} \times \frac{1-PAI}{PAI} \tag{2}$$

where P_{is} is the soluble P content. The stable P content could be assumed as a 4-fold of the absorbed pool size.

Organic phosphorus levels are set assuming that the N:P ratio for humic materials is 8:1.

6. Root architecture

If a plant is involved, a 3D root system simulation is required and the start point of the simulation is in the middle of growing period, root structure of standing plants to describe root system are required. A user-defined table is used to store the information. The availability of root systems stored in the database is managed by a table named rootsegment. It would not be recommended to construct a root system manually because the size of the system is huge. In this case, it is worth simulating the system at the beginning of growth period. It may use the results from a previous simulation that have a root system recorded in one of the output tables.

7. Root growing tips

If a plant is involved, a 3D root system simulation is required and the start point for the simulation is in the middle of growing period, information of each growing root tips of standing plants are required if roots are still potential for growth at the start of the simulation. A user-defined table is used to store the information. The availability of root systems stored in the database is managed by a table named roottip. Similarly to root architecture, it would not be recommended to construct growing roots manually because the size of the system is huge. In this case, it is worth simulating the system at the beginning of growth period. It may use the results from a previous simulation that have a root system recorded in one of the output tables. The information in this table, along with that is used for root architecture must be referred to the same root system.

Configuring a simulation for multiple fields

Supposing there are 6 fields to be simulated in a simulation ID. Among these fields, there are some hydrological/topological linkages (Figure 30). Field B will receive nutrients and water from field E and F. Similarly field A will get them from both field C and D. When the simulation is configured, first to click the function of field information under the Veiw/edit menu, then a child windows will pop up. The necessary information can be filled in (Figure 31).

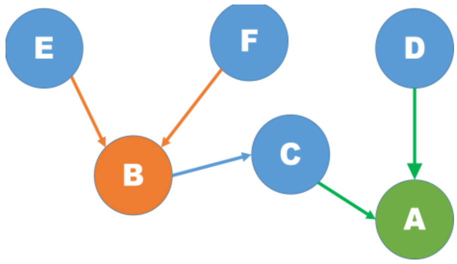


Figure 30. connections between fields

In the simulation, the topological sorting algorithm will be used to determine the order of simulating the fields at a time step. One possible option for the arrangement in Figure 30 is in the order of F, D, E, B, C and A. This will make sure that nutrients and water out of the fields will added to the recipient field before simulating the field at the same time.

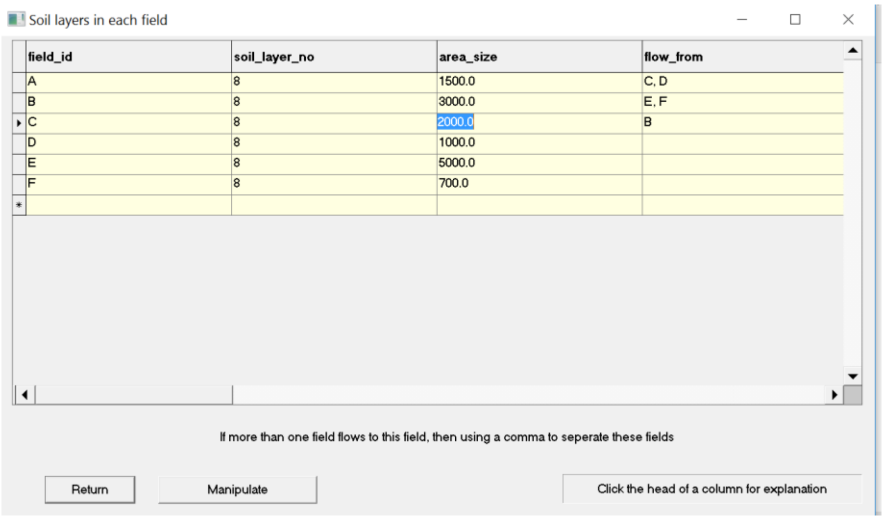


Figure 31. configuration of field connections

Tutorial on modelling a single cropping system

1. Double click on SPACSYS icon to open it.
2. From the **Connect** menu, choose **Connect to Database.** Choose the **Data Source** and click **Confirm data source selection**. Select the corresponding **Working database – "training_work"** and **Weather, soil property and plant database – "training_data".**
3. Click **OK.**
4. In the **File,** select either **Open an existing simulation** or **Copy a simulation setting**. In this example, we have chosen to work on the "**continuous_wheat**" simulation. If you have chosen to copy a simulation setting, double click on the desired simulation ID and write the name of the new simulation. Click **Selected.** Your new simulation ID is created. In the **File,** select **Open an existing simulation** and choose the newly created simulation. Click **Selected.**
5. On the bottom of the screen, you can check to which database you are connected - **Connected to:** and which simulation you are working on - **the Simulation ID:**

General information

6. Click **View/Edit** and choose **Edit parameters**. In principal, you need to write/change the **start_time** and **end_time** of the simulation**, Latitude** and **Longitude** of the site you are modelling, **CO2 concentration**. Select from the **table for weather data** tree, the weather data (which you created at the beginning in the database) for your simulation. Here it was already created for you so we choose "**weather_continuous**".
7. Select the simulation field from the **view/edit parameters in field** (for this example it is **A71**) and click the **Continue to view/edit parameters**. A window with the process controls and the parameters for the different processes appears. Choose the **Process controls**, if you double click on the margins near the process names and hoover over, you can see an explanation for each process controls.
8. In the **General information**, choose from the **table for soil property**, the soil specific for you site data – e.g. "soil_continuous". Write a number in in the **Root impenetrable depth where roots are difficult to penetrate through (m).**
   If you have chosen an existing simulation or copied one, all the fields in the **Plant parameters, Nitrogen parameters, Heat parameters, Water parameters** and **Water-heat interactions** are filled. Therefore, you need to change only some of them depending on the simulation.
9. Click **OK.**
10. Click **Save.**
11. Click **View/Edit** and choose **Initial variables**, there the ***Initial water, temp & salt status***, ***Initial C pools***, ***Initial N pool***, ***Initial plant status*** and ***Initial root distribution*** should be checked and modified depending on your simulation. For the example, here, it was done for you already.

Management

12. Click **View/Edit** and choose **Plant Management**, a window **Crop management** will pop out. Here using **Microsoft SQL Server Management Studio**, we insert sowing and harvest dates as well as if it is a grazing system how much the animals eat per day. Importantly, the **field_id** should be the same you have chosen in **step 7**. The **plant_code** you should have chosen from **General parameters**, select **Plant parameters**, click on the **Edit existing dataset** (or create a new variety using **Create a dataset**).
13. Click **RETURN.**
14. Click **View/Edit** and choose **Fertilizer application**, a window **Fertilizer application** will pop out. Here using again **Microsoft SQL Server Management Studio**, we fill in the fertilizer applications for the required period. If you double click on the table column headers, you can see a detailed explanation for the codes used.
15. Click **RETURN.**
16. Click **View/Edit** and choose **Field management**, a window **Field management** will pop out. Here you insert the ploughing events for your field.
17. Click **RETURN.**
18. Click **View/Edit** and choose **Field information**, a window **Soil layers in each field** will pop out. In **soil_layer_no** we insert the numbers of soil layers we have.
19. Click **RETURN**

20. Click **View/Edit** and choose **Soil layer information**, a window **Soil layer information** will pop out. Here we insert the thickness (**thickness**) of each individual soil layer (**soil_layer**).
21. Click **RETURN.**

Simulation

22. Click **Simulation** and select **Run a simulation.** You will see at the bottom of the screen ***Simulation running*** so wait until you see ***Run successfully***. Congratulations! You have just run your first simulation!

Simulation Analysis

23. Click **Simulation Analysis** where you can find all the outputs from your simulation. Select **Plant**, then **Plant Harvest** and a window with the data comes out. Click **SAVE AS** and write a file name, save as a .csv file and click **Save**. You have created an excel file which you can use to visualise the obtained results. Now open the created excel file and plot the yield ("first_plant_economic_organ_DM") for the three years (Figure 32).

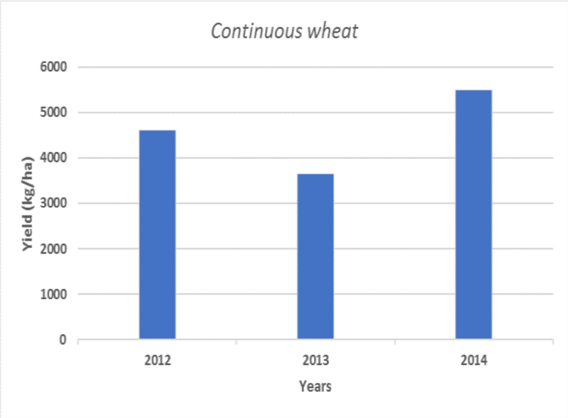


Figure 32. Winter wheat yield

24. Click again **Simulation Analysis** tree**,** choose **Water content** at the bottom of the list. and a window with the data comes out. Click **SAVE AS** and write a file name, save as .csv and click **Save**. Now open the created excel file and plot the soil water content for the first three layers (Figure 33).

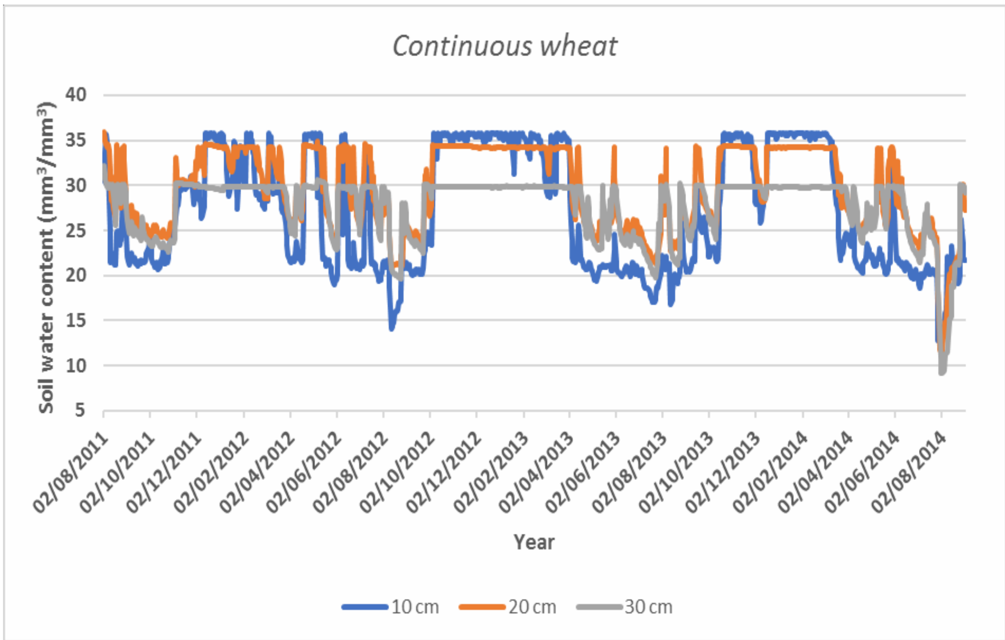
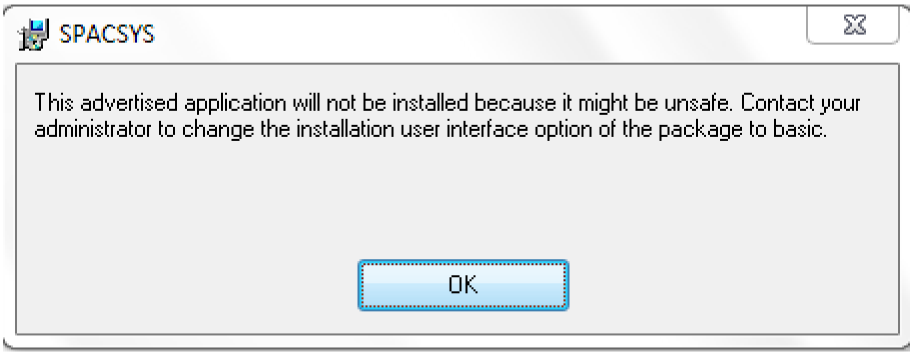


Figure 33. Soil water content in different soil layers (0-10, 10-20 and

Troubleshooter

The software cannot be installed

When running setup.exe or setup.msi, Windows Installer displays a message similar to this: 'This advertised application will not be installed because it might be unsafe. Contact your administrator to change the installation user interface option of the package to basic'.



This error typically occurs when SPACSYS has been already been partially installed on your machine. In this scenario, SPACSYS is advertised on your computer as being available to use, and will be installed when you try to run it for the first time using the SPACSYS item in the **Start** menu. Therefore, there are three options to setup the software:

1) Click on SPACSYS in the **Start** menu to complete installation.

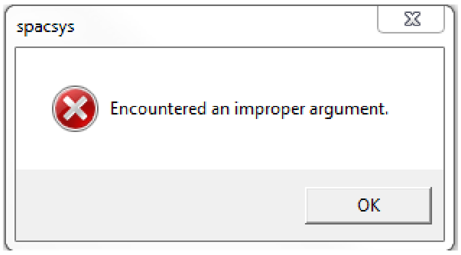
2) Open the **Control Panel** and then **Add/Remove Programs** (Windows XP) or **Programs and Features** (Windows Vista and later). Locate the SPACSYS entry in the list of installed applications, and use the controls to uninstall it. You can then install SPACSYS from the setup package that you have downloaded.

3) Open a command prompt and cd to the folder where you saved the setup.*msi* file. then run the *msiexec* program as follows:

    msiexec /qb /i setup.msi

Encountered an improper argument error message

When the software is opened for the first time, it may appear the following error message:



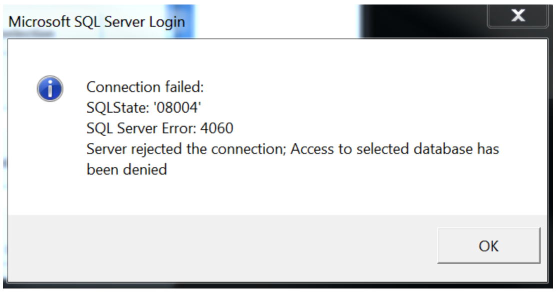
This is because no information about connected database stored in the register profile of the machine. Simply click OK button on the error message windows to continue.

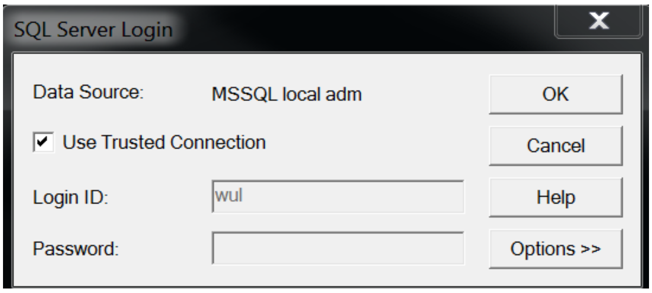
Can't find out a table to store weather data or soil physical properties

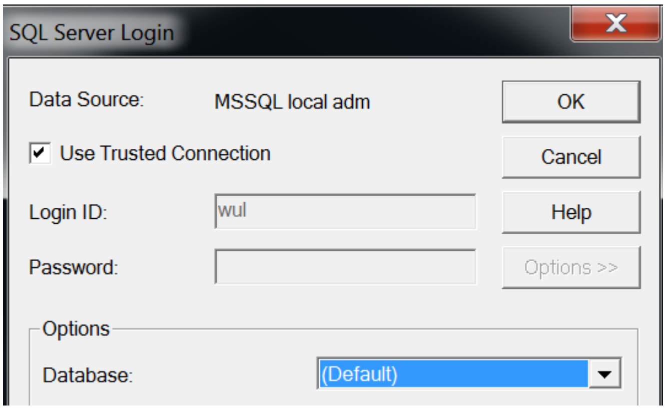
If a table has been created but cannot be shown in a drop-down list in the windows popped up from view parameters in the menu bar for a simulation. The table may be not logged in the relevant profile table. To enable the table to be shown, open the climatesites table for weather data or the soilprofile table for soil physical properties in the data database and add the table name into the table.

Access to selected database denied

Durng operations, you might receive the message shown in the figure. Sometime this is caused by incomplete database connection. To solve the problem, click "OK" in the figure first. And then a child window will popup. To click "Options>>" button and then you will see the options. In the dropdown list of Database, choose "default" and click "OK". The databases should be linked correctly.







SPACSYS displays neither configured information nor simulation results for a chosen simulation ID

In an extreme situaton, you might be unable to show configured information, e.g. field information (shown in the figure below), or simulation results, e.g. soil temperature, after you chose a simulation ID. The problem might be caused by microsoft.NET framework. You should make sure microsoft.NET framework 4.6 or over installed on your machine.