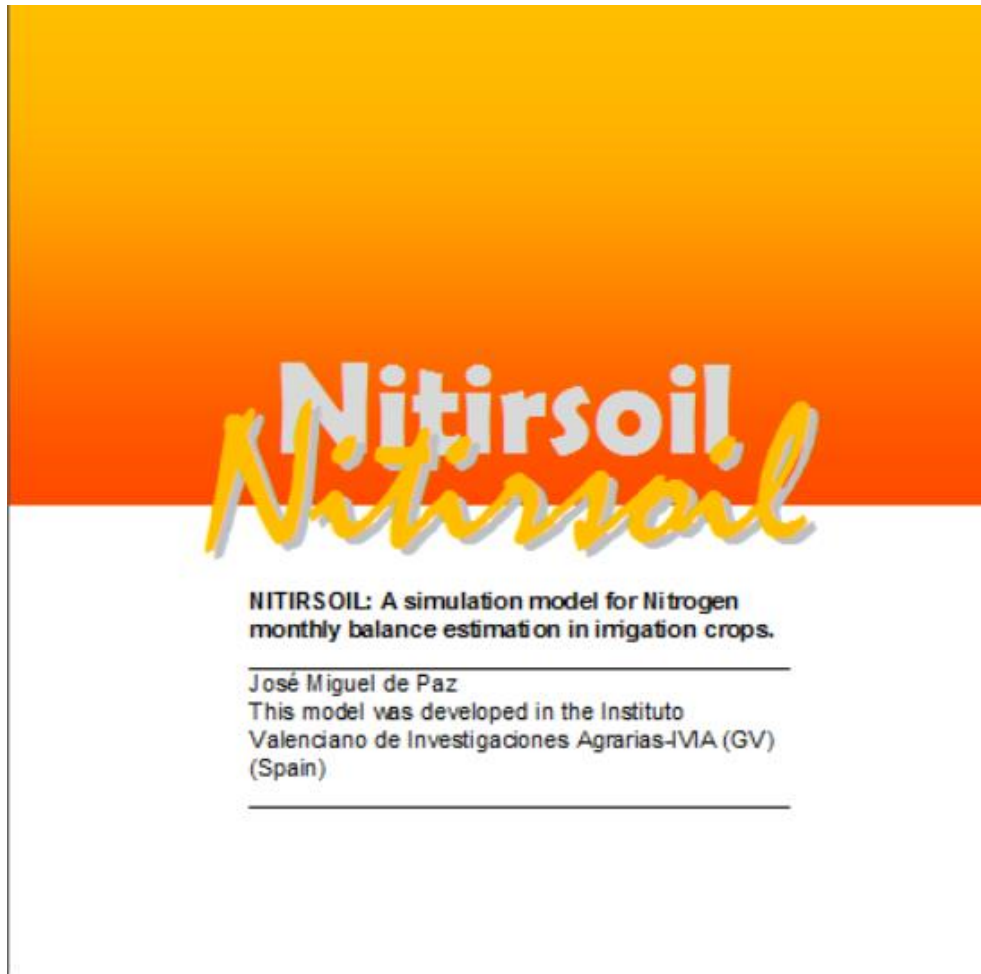


OPERATION MANUAL AND DESCRIPTION OF THE NITIRSOIL MODEL



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I) NITIRSOIL model operation manual

1. Introduction

To date, many models have been developed to evaluate the effects of agricultural nitrogen management on crop production, and on N losses to the environment. These models can range from very complex, which have the objective of accurately quantifying the movement and transformation of N, to simple indices that serve to qualitatively evaluate the management that is being carried out.

Within all the complexity gradation of the models, the user must select one according to the objectives for which they want to use the simulation model.

To select a simulation model, Shaffer and Delgado (2001) propose the idea of confronting the theoretical points of view with the practical ones. In this way, they suggest selecting as more likely, a model of intermediate complexity for its application in the field as shown in Figure 1.

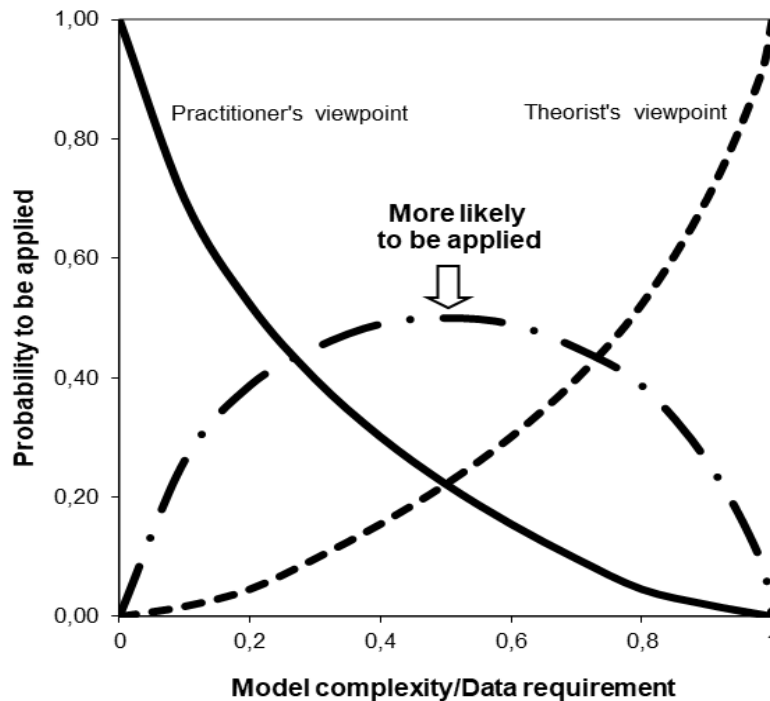


Figure 1. Selection of the best model for its application in the field (adapted from Shaffer and Delgado 2001)

This idea has led them to classify the models in a system of three levels of complexity in terms of processes that are considered, and information requirements, and therefore, to help choosing the most appropriate according to the simulation objectives.

At a first level of complexity, the objective is a qualitative evaluation of management practices, for which models such as the Nitrogen Index are suitable (Delgado et al. 2006, 2008, Delgado 2020, De Paz et al. 2009). These simple models are adequate for establishing indicators that alert us about some risk.

At a second level of complexity there are models that quantitatively evaluate the dynamics of N, such as el NLEAP (Shaffer et al. 1991, 2001, 2010), EU_ROTATE-N for european vegetable crops (Rahn et al. 2010), VEGSYST mainly focus in modelling greenhouses conditions (Gallardo et al 2014), or the Italian model GesCoN (Elia and Conversa 2015) also focused on vegetable crops.

At a third level of complexity there are models that require a large number of parameters and input data and algorithms, such as LEACHM-N (Wagenet and Hutson 1989), CERES (Ritchie et al 1989), DSSAT (Jones et al 2003), CROPSYST (Stöckle et al 1994) STICS (Brisson et al 1998), ANIMO (Berghuijs et al 1985), DNDC (Li 2012) etc. These models are best suited for research and the study of the N dynamic in the agricultural ecosystems.

When choosing a model that can be used to make recommendations of nitrogen fertilizer management, Shaffer and Delgado (2001) suggest choosing models with intermediate complexity such as level 2. These models should have the sufficient precision in its predictions, and at the same time use the minimum number of parameters within the model, and input data to meet the proposed objectives.

2. Objective of the model

The main objective of the NITIRSOIL model is to carry out monthly estimations of nitrogen balance in soils under irrigation with horticultural and citrus crops, using for that the least possible number of data and parameters, but without losing excessive precision, so that the estimations serve as a basis for giving management recommendations of nitrogen fertilization.

With the objective of improving the model applicability and to ease the data input, along with the model a database of climate, soil, crops, fertilizers has been implemented. The model is distributed along with this database, which by default contains information about some European countries (Denmark, Germany, Italy, Norway, Spain, and United Kingdom), so that the users from this territory can directly select the data that best fit their case simply knowing the location of the fields of their interest. Notwithstanding this, the users not from these European countries can also benefit from the use of the model. For this they can easily include the adequate information for their case in the database, and carry out the simulations of the crop fields of their interest.

3. Model general description

The NITIRSOIL model is made of three main modules. Firstly, a module of water balance which uses the algorithms of the SALTIRSOIL_M model so as to simulate the water dynamics in the soil-water-plant-atmosphere system (Visconti and de Paz 2012, Visconti et al. 2014). Secondly, a module of crop development so as to simulate the dry matter production, both harvested and total. Finally, a nitrogen module so as to simulate the N dynamics in the soil-water-plant-atmosphere system.

The main N contributions the NITIRSOIL considers are: i) the mineral fertilization, ii) the organic fertilization, iii) the nitrate dissolved in the irrigation water, iv) the nitrate yielded by the soil organic matter mineralization, v) the nitrate yielded by the crop residues mineralization, vi) the nitrate dissolved in the rainfall water, and vii) the soil mineral nitrogen at the onset of the crop or fertilization season.

The main N transformations the NITIRSOIL considers are: i) mineralization, ii) nitrification, iii) denitrification, and iv) ammonium volatilization (Fig. 2).

The main N outputs the NITIRSOIL considers are: i) the crop N uptake, ii) the nitrate losses by leaching, iii) the nitrogen losses by denitrification in the form of N_2 , iv) by nitrification and denitrification in the form of the greenhouse gas N_2O , and v) by ammonium volatilization in the form of NH_3 .

The codification of the nitrogen module is based on the algorithms used by the NLEAP model (Nitrate Loss and Environmental Assessment Package) (Shaffer et al. 1991, 2010), including also the algorithms of the EU-ROTATE_N model (Rhan et al. 2010) regarding the crop nitrogen uptake assessment, and the WNMM model (Water and Nitrogen Management Model) (Li et al. 2007), and NOE (Nitrous Oxide Emission) (Hénault et al. 2005) for the estimation of the N_2O greenhouse gas emissions.

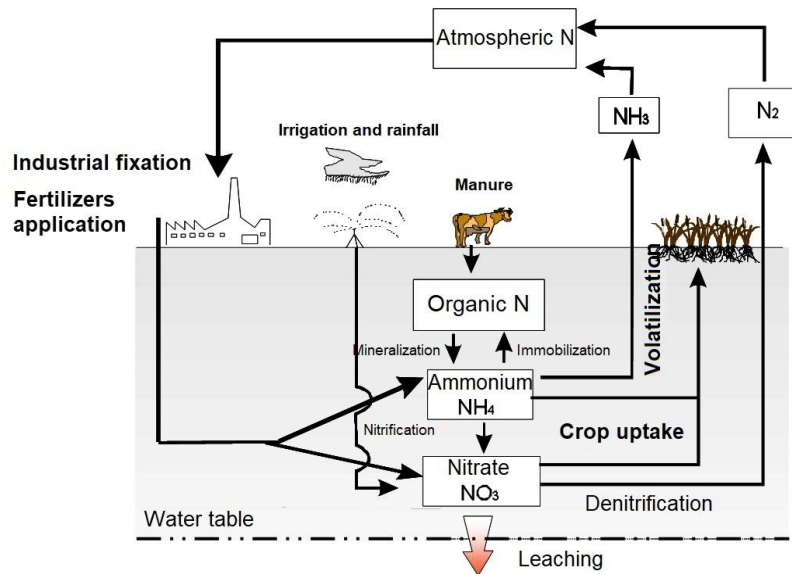


Figure 2. Nitrogen cycle processes considered by the NITIRSOIL model

The model consists of three different parts: i) data input, ii) modeling and iii) data output (figure 3). The user can directly enter the specific data of his field by interacting with a graphical user interface or directly entering the data in a series of tables stored in a database in MsAccess© format. For a better and easy management of the model, several databases have been implemented where the information on soils, waters, crops and climate are stored. Specifically, these databases have included data from the main crop areas of several European countries:

- Soils: data from 83 sampling points located in the main cultivation areas of the european countries
- Weather: data from 90 weather stations split in some European countries
- Crop: parameters of 41 horticultural crops and 10 multiannual crops (citrus).

The modelling part is where all the calculations are made to estimate the main terms of the water and nitrogen balance and the dry matter production of the crop on a monthly basis. These calculations are carried out in 3 different modules (Water, production and nitrogen) that are interrelated with each other (figure 3).

The data output part presents the results of the monthly balances of water and nitrogen considering the depth selected by the user at the beginning of the simulation. In base on the nitrogen balance, the model calculates 2 indicators related with the efficiency, one is the of nitrogen use efficiency (NUE) by the crop, and another on the excess of nitrogen application (Nexcess). Additionally, it also makes an estimation of the potential losses production due to a poor management of the nitrogen fertilizer. This last indicator is assessed comparing the nitrogen potential uptake with the real one. If the nitrogen uptake by the crop is lower than 90% of that potentially uptake, the model indicates a potential nutritional deficiency. The model also calculates 2 indicators for the water use efficiency by the crop, one for irrigation water management, and another related with the crop evapotranspiration efficiency.

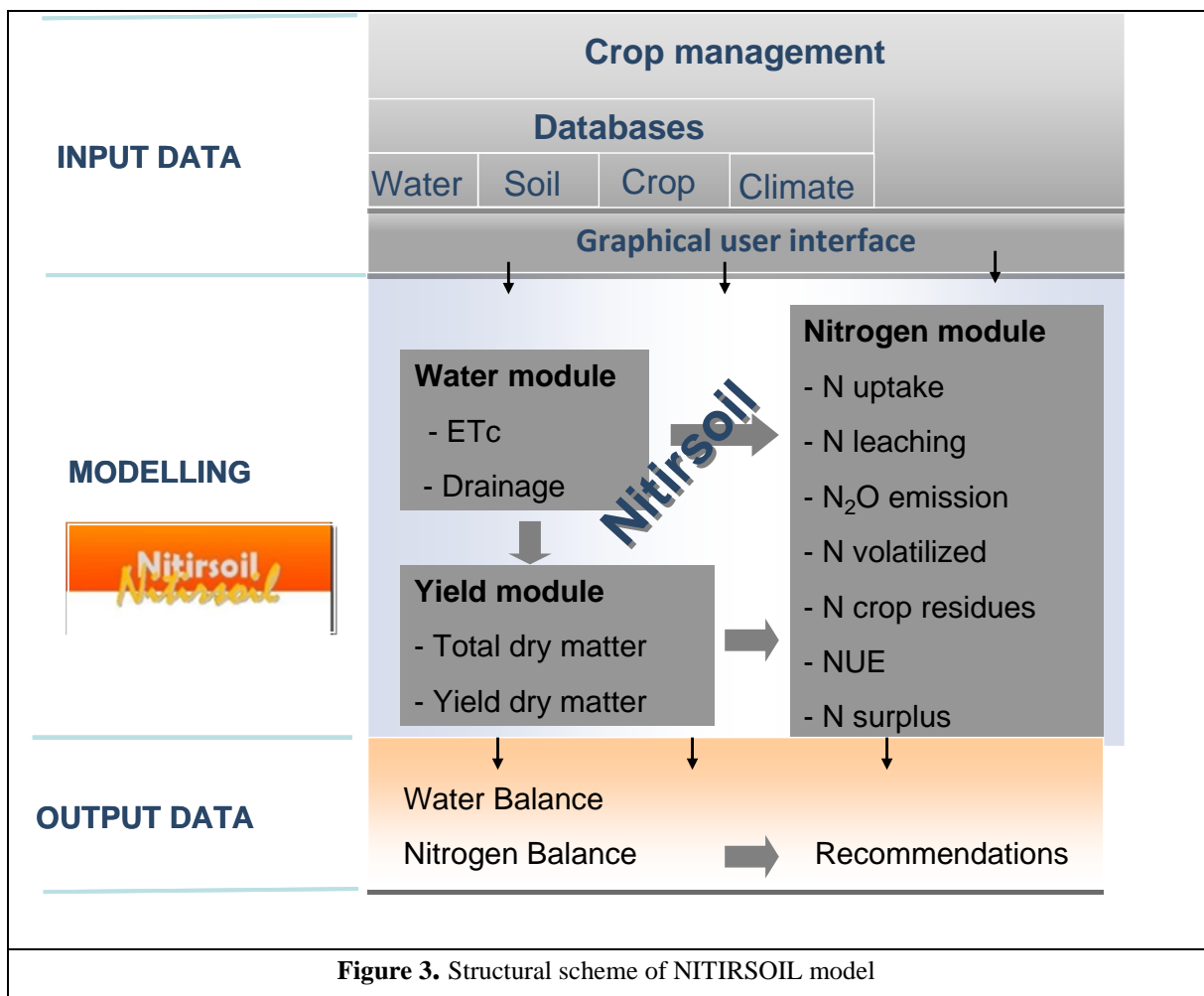


Figure 3. Structural scheme of NITIRSOIL model

NITIRSOIL is a model that has been developed in a standard programming language such as the Visual Basic.NET with access to MS Access© databases, and thus it can be installed in whichever personal computer with the MS Windows© operating system.

Two versions of the NITIRSOIL model have been developed. In the first one, of the *windows* kind, the user interacts with a graphical interface that has been especially designed for the model, and which includes various menus for data input and database access, etc., (Fig. 4). In the second one, of the *batch* kind, the user must operate the MS Access© so as to directly enter the simulation data into several tables in the

nitirsoil_batch.mdb database (Fig. 5). This version allows the model to be batch run and therefore many simulations can be carried out, one after another, taking the input data from the nitirsoil_batch.mdb database and, writing and saving the results directly in the same database. This batch version has been created with the objective of easily implementing the model in an on-line system with database access.

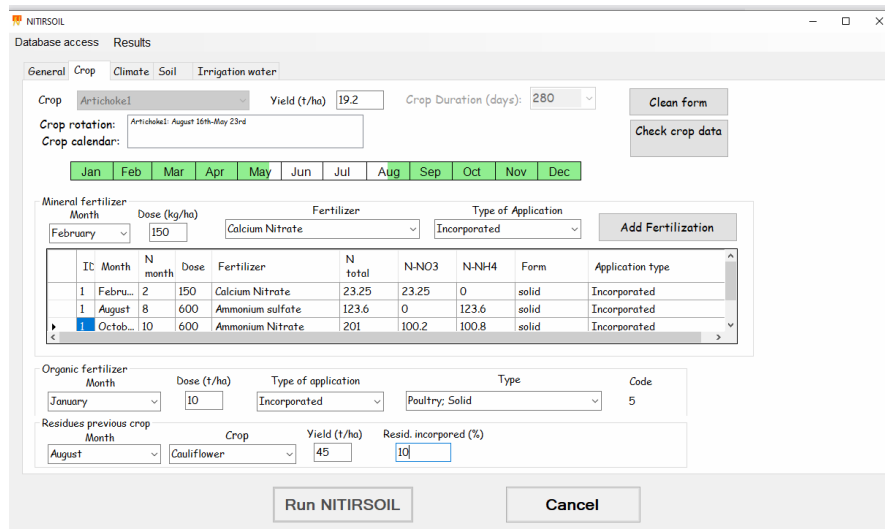


Figure 4. Graphical user interface of the NITIRSOIL windows version

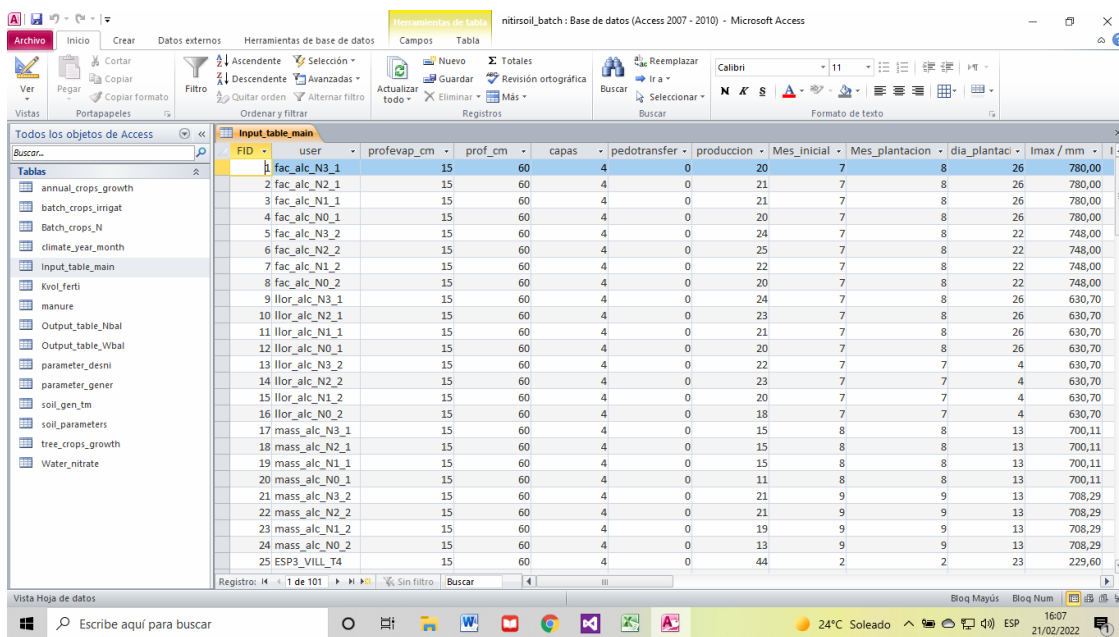


Figure 5. In the batch version of the NITIRSOIL model the user enters the data directly in the nitirsoil_batch.mdb database

4. Model management

4.1. Windows version

The graphical user interface is structured by means of a menu bar and a working area. The software menu bar presents three drop-down menu options.

The first menu option is [Database access]. As described in detail in sections 5 and 6, from this menu option the user can access various dialog boxes through which to view data, modify it, and delete and add records to the tables of model parameters, and of data on soil, climate, crop, as well as mineral and organic fertilizers.

The second menu option is [Results]. From this menu option the user can access some dialog boxes, which allow them make use of a series of tools that ease the retrieval of the results from the nitrsoil.mdb database, and their visualization in table and graph formats, and to erase those tables of results that are not of their interest any more.

The third menu option is [Load simulations]. From this option the user can choose the previous simulations performed and load to the system easily.

4.1.1. Guidelines for data input

The simulations are performed from the software working area, which is arranged according to several tabs, which are sequentially activated as the user completes the data required for the simulation, and which can be of general kind, crop and fertilization, irrigation, soil and water quality (Fig. 6). These tabs contain the dialog boxes, which with the user interacts to enter and select the data that are required to perform the simulations.

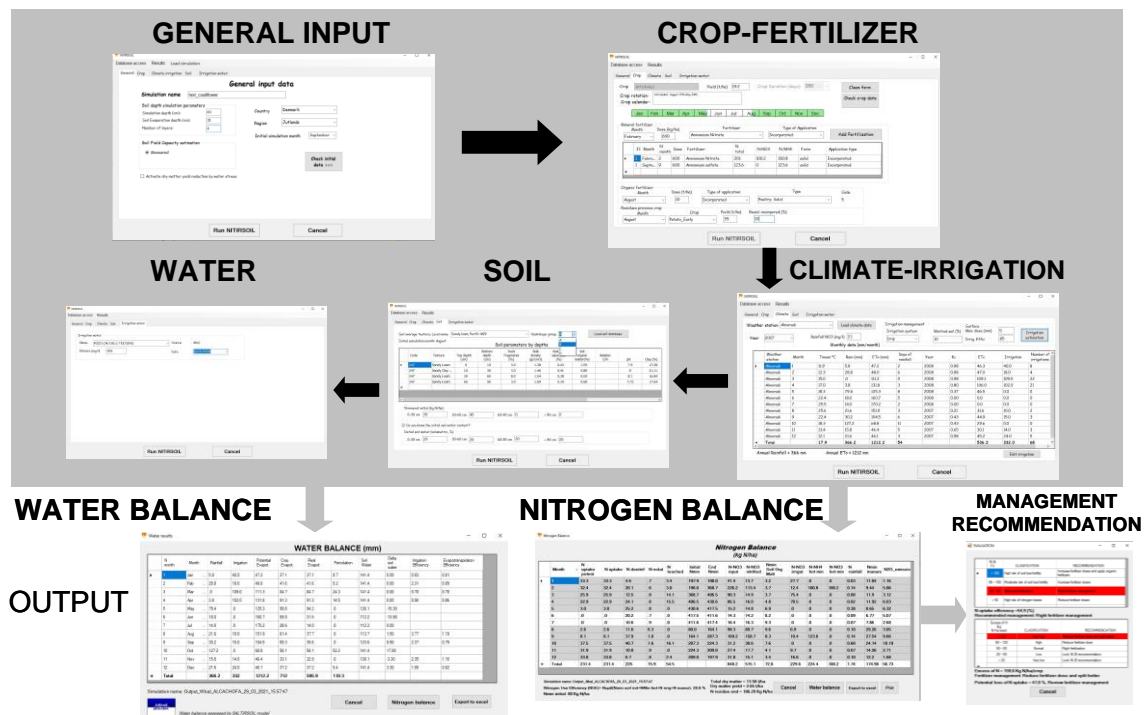


Figure 6. Tabs in which the software working area is arranged, and which are sequentially filled to input the data

4.1.1.1. General data

In this general input menu, the user must enter (Fig. 7):

- The name of the simulation in the text box “Simulation name”. The user can enter whatever name for the simulation. Afterwards the model will add to that name the date and time where the simulation was performed so as to save the results in the database.
- The soil depth down to which the simulation is intended in the box “Simulation depth (cm)”. In case the user wants to simulate depths below the maximum soil depth (in the soil data table), the model, due to an integrity constraint, will choose the soil depth as the simulation depth. Besides, if the maximum rooting depth is further below the simulation depth, the model will take the maximum rooting depth as the simulation depth.
- The depth from which the model considers that water can be evaporated in the box “Soil Evaporation depth (cm)”. By default the model takes the value of 15 cm
- The number of layers in which the simulation depth is conceptually split in order to perform the calculation in the box “Number of layers”. By default, they are 4 layers, enough to perform the simulation in the rooting depth of most crops. The more layers the model will take longer doing the simulations.

Also, an option has been added to enable the user to activate that the dry matter production be diminished in case the model detects that a water stress has occurred.

The screenshot shows the 'General input data' window of the NITIRSOIL model. The window has a title bar with 'NITIRSOIL' and standard window controls. Below the title bar are three tabs: 'Database access', 'Results', and 'Load simulation'. The 'General' tab is selected, and it contains several input fields and a checkbox. The 'Simulation name' field contains 'test_cauliflower'. The 'Soil depth simulation parameters' section includes 'Simulation depth (cm)' (60), 'Soil Evaporation depth (cm)' (15), and 'Number of layers' (4). The 'Country' dropdown is set to 'Denmark', and the 'Region' dropdown is set to 'Jutlands'. The 'Initial simulation month' dropdown is set to 'September'. There is a 'Soil Field Capacity estimation' section with a radio button for 'Measured' selected. A checkbox for 'Activate dry matter yield reduction by water stress' is present and unchecked. A 'Check initial data >>>' button is located on the right. At the bottom, there are 'Run NITIRSOIL' and 'Cancel' buttons.

Figure 7. Tab of the general data menu of the NITIRSOIL model

In case the user is located in some european country in which the model has information, an option has been implemented to enable them to select the country and region where the plot is going to be simulated. With this information the model is able to select the soil and climate data of the chosen region from the database. This information comes from the results of the project “Development of a model based

decision support system to optimise nitrogen use in horticultural crop rotations across Europe”, EU-ROTATE_N. QLRT-2001-01100.

In this menu the user can also select the initial month of the simulation. This value could be changed when the plantation date is selected afterwards. In this case the month when the plantation takes place will be selected. Later, this simulation initial month can be changed by the user themselves.

Once the input data has finished in this menu, the [Check initial data >>>] button is pressed for the model to check if all the input data in this menu are right. If so, it will enable the next tab for the crop data input.

4.1.1.2. Crop management and nitrogen fertilization

In the input menu for the crop management data, which is shown in Fig. 8, the user must select, firstly, the crop that they are going to simulate. For this regard they must unfold the list of crops and select the appropriate. Once the crop has been selected, the model offers a production value, and a crop length by default, which the user can change for adaptation to the actual situation of their interest. In this list are included several horticultural and citrus crops. The next step consists in selecting in the crop calendar bar the plantation day. To do this, the user must move the mouse pointer over the calendar bar and click on the day that has been selected for the plantation. For the woody crops, which are multiannual, the growth length is considered to be 365 days, and the beginning of the season is considered to be 1st January.

Afterwards, by means of the dialog box in the group “Mineral fertilizer” the user can add to the simulation the nitrogen fertilizer that will apply each month. This will be done by selecting the month, the rate, and the type of fertilizer, and the method through which is incorporated to the soil. Later, by means of the [Add Fertilization] button they will add the fertilizer to the fertilizers table, and the fertilizing data will appear on the mineral fertilizer table. In case the user wants to delete some fertilization, this will be achieved simply by selecting with the mouse the record from the table, and pressing the [Supr] key on the computer keyboard. Since the model is monthly based, just one fertilizer application per month is allowed in the model, so in case of several fertilizations in one month, the user should group in just one application.

In the same way in the dialog box within the group “Organic fertilizer”, the user can add a single organic fertilizer a year by selecting the application month, the rate in t/ha, the type of application (surface, incorporated, etc.), and the type of organic fertilizer (poultry droppings, beef manure, etc.).

In this menu the user can also enter the data of the incorporated residues from the previous crop (group “Residues previous crop”). This way, the model can estimate the nitrogen contributions due to the mineralization of these residues during the development of the actual crop. For this purpose, the user must enter the data from the previous crop, its production, the percent of residues that have been incorporated to the soil and the incorporation month (in general the month of the present plantation itself or some previous month, but never before the beginning of the simulation).

If one user wants to select another management and/or crop, the [Clean form] button is clicked on the top right. As a consequence, all the input data will be deleted from this menu, and another crop data input can begin.

Database access Results Load simulation

General Crop Climate irrigation Soil Irrigation water

Crop: Cauliflower Yield (t/ha): 41,7 Crop Duration (days): 144

Crop rotation: Cauliflower: September 14th-February 5th

Crop calendar: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Mineral fertilizer

IT	Month	N month	Dose	Fertilizer	N total	N-NO3	N-NH4	Form	Application type
1	Janua...	1	300	Ammonium Nitrate	100,5	50,1	50,4	solid	Incorporated
1	Septe...	9	600	Ammonium sulfate	120	0	120	solid	Incorporated
1	Nove...	11	300	Ammonium Nitrate	100,5	50,1	50,4	solid	Incorporated

Organic fertilizer

Residues previous crop

Run NITIRSOIL Cancel

Figure 8. Input menu for the crop management data

Once the filling of this menu has finished the [Check crop data] button is pressed. The model will check if all the data are right and, if so, it will enable the following tab for the climate and irrigation data input.

4.1.1.3. Climate and irrigation

The menu for the climate and irrigation management data input is shown in Fig. 9. For the input of the climate date the user has two options.

The first option is to use the climate data from the database that has been implemented with all the weather stations from some countries of Europe. In this case, the model interface will offer the weather stations for the selected regions in the general input menu. Once the weather station has been selected, the year that one wants to simulate can be selected, and the appropriate climate data will be shown on the window. The user can directly modify these data on the table that is shown.

Another option is to load a particular climate data table through the [Load climate data] button. In order to use this option, the user must have previously prepared their own table with the climate data from the weather stations and years they intend to use in the simulations. This table must be located in the “nitirsoil.mdb” database, and its name must begin by “Climate_”, and then the name the user wants, e.g., “Climate_user”. Once the climate table has been loaded, and the weather station and year to simulate have been selected, the climate data will be shown on screen, which can also be directly edited on the table that is shown.

Next, the irrigation scheduling of the simulation comes, for which the model can make an estimation. Therefore, firstly, the user must enter the maximum irrigation rate in each application in mm, as well as the application efficiency, which takes by default the following values depending on the type of irrigation technique: 0.65 by flood, 0.75 by

furrows, and 0.85 by drip. Then, after pressing the [Irrigation estimation] button the model will make an initial irrigation recommendation, and simultaneously will enable the [Edit irrigation] button. If the user presses this last button they will access a dialog box (Fig. 10), where they will be able to enter their own irrigation data or load some irrigation scheduling from other simulations already performed with the model from the “Batch_crops_irrigat” table within the “nitirsoil.mdb” database. Once the data in this dialog box has been fulfilled, the next tab for the input of soil data will be enabled.

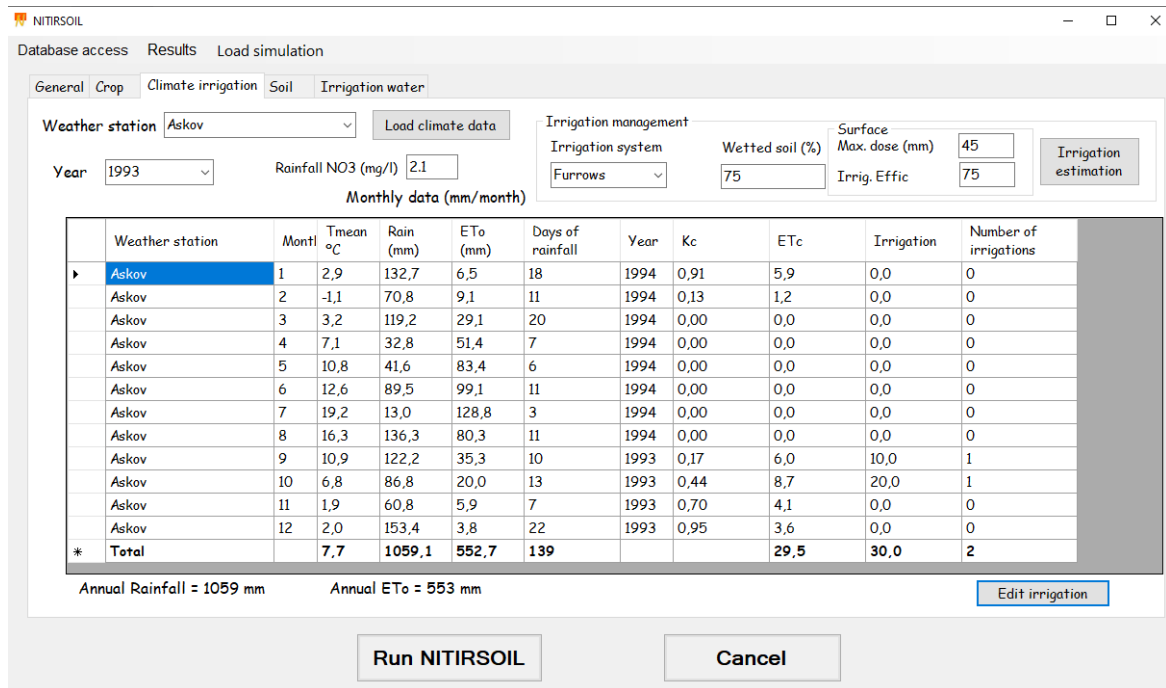


Figure 9. Input menu for the climate and irrigation data

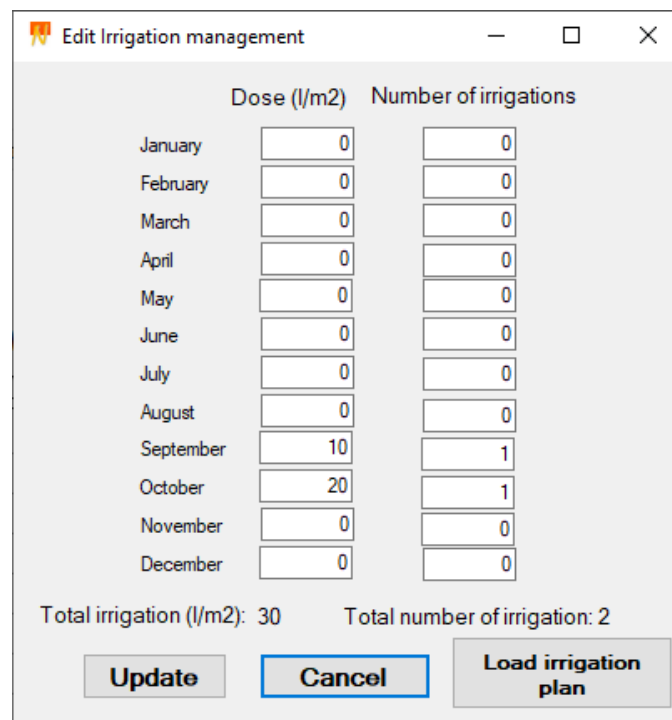


Figure 10. Menu for the edition of the irrigation management

4.1.1.4. Soil

The menu for soil data input is shown in Fig. 11. In this menu the user can enter the soil data by means of two options.

The first option consists in selecting the soil data from some European countries, which are saved in the database for the region that the user has selected in the general input menu of the model. The second option consists in loading a table with soil data that has been previously created by the user. This is the adequate option for the user who has specific data for the plots of their interest. In order to use this last option, the user must press the [Load soil database] button, and select the soil table which they have previously created. The table the user can load must have a specific structure (section 7.3), be included in the “nitrsoil.mdb” database, and with a name that begins with “Soil_”, e.g., “Soil_user”.

The user can edit and change the data that are shown on the table itself in this menu. These edited data will be used in the simulation but the soil table in the database will not be modified. In order to change the soil data in the database, the user must open the appropriate dialog box from the drop-down menu [Database access → Soil].

Next, the user must enter the values of the soil mineral nitrogen content (kg N/ha) at the onset of the crop for the soil layers of 0-30, 30-60, 60-90, and > 90 cm. If the simulation depth is less or equal to 60 cm, the mineral N of the 60-90 and > 90 cm can be zero since they will not be considered for the simulation.

If the user has information about the initial soil water content, they can also enter it in volumetric percentage units for the 0-30, 30-60, 60-90, and > 90 cm layers. If they do not have this information they have to uncheck the appropriate checkbox, and the model will make an estimation of the initial soil water content by means of a previous simulation. Once the soil data input is finished, the following tab of irrigation water quality will be enabled.

Soil average texture; Local name: Hydrologic group:

Initial simulation month: September

soil_id	Texture	Top depth (cm)	Bottom depth (cm)	Rock Fragments (%)	Bulk density (gr/cm ³)	Water at saturation (%)	Soil organic matter(%)	Relation C/N	pH	Clay (%)
11	Loamy Sand	0	29	0,0	1,50	0,43	2,69		6,1	5,00
11	Sand	29	56	0,0	1,58	0,40	0,67		5,1	3,00
11	Sandy Loam	56	80	0,0	1,83	0,31	0,50		5,5	6,00

N mineral initial (kg N/ha)

0-30 cm 30-60 cm 60-90 cm > 90 cm

Do you know the initial soil water content?

Initial soil water (volumetric, %)

0-30 cm 30-60 cm 60-90 cm > 90 cm

Figure 11. Menu for the soil data input

4.1.1.5. Irrigation water

In the menu for irrigation water quality data input, which is shown in Fig. 12, the user can select the irrigation water according to its nitrate concentration. A database structure is included in the model proposing 5 types of waters, depending on the nitrate concentrations (mg/L).

- Low: 10 mg/l
- Moderate: 25 mg/l
- High: 50 mg/l
- Very High: 150 mg/l

The user can change the concentration value in the text box “Nitrate (mg/l)”. The model does not allow using different nitrate concentrations for the different months of the year to simulate. It only allows using one single irrigation water quality per simulation.

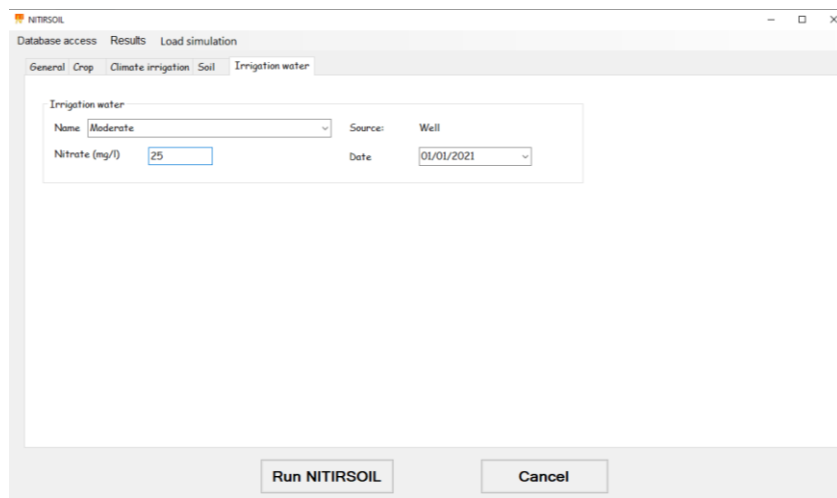


Figure 12. Menu for the irrigation water data input

4.1.2. Model run and results

Once all the input data have been entered, the user must click the [Run NITIRSOIL] button, and a dialog box (Fig. 13) will pop-up, that indicates the name of the simulation with which the model will write the input data tables in 4 tables of the “nitirsoil.mdb” database:

- General data in “Input_table_main”,
- Basal crop coefficients and rooting depth in the “Batch_Crops_Growth”
- Irrigation rates and frequency in the “Batch_Crops_Irrigat”
- Nitrogen fertilization management in the “Batch_crops_N”

The irrigation scheduling data can be retrieved by the user from the “Batch_Crops_Irrigat” table by using the name of the simulation in the irrigation editing button (button [Load irrigation plan]) on the “Climate irrigation” tab, and the whole simulation with the drop-down menu “Load simulations” included in the interface of the model.

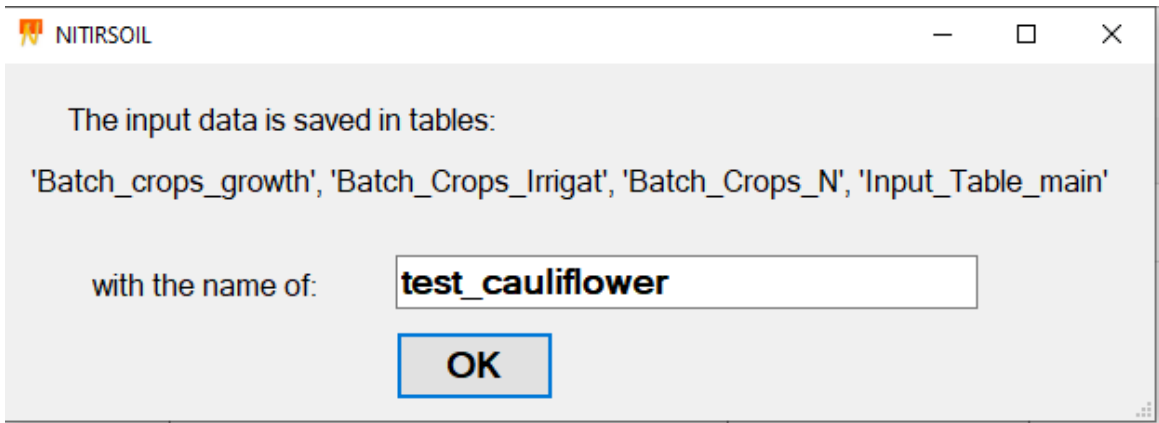


Figure 13. Dialog box that warns the user to save the simulation data input

Next, the [OK] button is pressed, and the model will perform the simulation, and a dialog box will appear with the nitrogen balance table that has been simulated by the model.

4.1.2.2. Results of the nitrogen balance

In the first dialog box appeared (Fig. 14) are showed the main terms of the nitrogen balance simulated by the model month by month in kg N/ha units in the simulated depth input by the user.

Month	N uptake potent	N uptake	N denitrif	N volat	N leached	Initial Nmin	End Nmin	N-NO3 input	N-NO3 nitrified	Nmin Soil Org Matt	N-NO3 irrigat	N-NH4 fert min	N-NO3 fert min	N rainfall	Nmin manure	N min resid	N2O_emission
1	81.2	40.6	1.8	.0	.4	.5	27.5	69.8	19.1	3.6	.0	50.4	50.1	0.63	.0	.0	.45
2	30.7	13.9	.7	.7	.0	27.5	25.4	12.5	12.2	2.0	.0	.0	.0	0.34	.0	.0	.17
3	.0	.0	1.8	1.4	.0	25.4	43.8	20.2	19.6	3.9	.0	.0	.0	0.57	.0	.0	.46
4	.0	.0	1.1	.6	.7	43.8	54.1	12.1	11.9	3.6	.0	.0	.0	0.16	.0	.0	.27
5	.0	.0	1.4	.2	.0	54.1	57.5	4.8	4.6	4.8	.0	.0	.0	0.20	.0	.0	.34
6	.0	.0	3.3	.3	3.7	57.5	57.1	6.6	6.2	6.5	.0	.0	.0	0.42	.0	.0	.83
7	.0	.0	1.6	.4	.0	57.1	63.4	7.9	7.9	8.3	.0	.0	.0	0.06	.0	.0	.41
8	.0	.0	5.5	.4	11.2	63.4	55.8	9.1	8.4	8.9	.0	.0	.0	0.65	.0	.0	1.37
9	11.5	11.5	3.6	.4	16.3	60.0	65.8	37.2	36.1	5.4	.6	120.0	.0	0.58	.0	.0	.91
10	51.6	31.5	2.1	1.9	15.6	65.8	44.6	28.1	26.6	4.3	1.1	.0	.0	0.41	.0	.0	.54
11	97.0	71.3	.0	.0	9.5	44.6	31.2	67.4	17.0	2.3	.0	50.4	50.1	0.29	.0	.0	.0
12	100.2	25.5	.0	.0	23.7	31.2	.5	18.4	17.7	3.7	.0	.0	.0	0.73	.0	.0	.0
* Total	372.2	194.3	22.9	6.3	81.1			294.1	187.3	57.3	1.7	220.8	100.2	5.04	0	0	5.75

Simulation name: Output_Nbal_test_cauliflower_07_04_2022_9:39:47
 Nitrogen Use Efficiency (NUE)= Nupt/(Nmin soil init+NMin fert+N irrig+N manur)= 54.9 %
 N surplus = Ninput - Nuptake = 159.6 Kg N/ha/year

Total dry matter = 10.84 t/ha
 Dry matter yield = 2.71 t/ha
 N residue end = 145.73 Kg N/ha

Figure 14. Dialog box with the table where the terms of the monthly nitrogen balance that results from the simulation are presented

The columns of the nitrogen balance table contain the information that is described below:

- Month: month in number format from 1 to 12,
- N uptake potent: potential plant N uptake, this is the one that would occur if there were not soil N deficit. Besides, if the option to diminish the dry matter production due to water stress is checked, the potential plant N uptake is decreased too,

- N uptake: actual plant N uptake. If the soil mineral N cannot meet the crop requirements this N uptake value will be less than the N uptake potent,
- N denitrif: nitrogen lost to the atmosphere as N_2 by denitrification,
- N volat: nitrogen lost as NH_3 to the atmosphere by ammonium volatilization,
- N leached: $N-NO_3^-$ lost to the underground waters by leaching,
- Initial Nmin: soil mineral nitrogen at the onset of each month within the simulation depth,
- End Nmin: soil mineral nitrogen at the end of each month within the simulation depth,
- N-NO3 input: total $N-NO_3^-$ input each month. Here the $N-NO_3^-$ that is generated by nitrification, contributed by the mineral and organic fertilization, irrigation, rainfall, and crop residues is added,
- N-NO3 nitrified: the $N-NO_3^-$ generated by nitrification of the soil ammonium,
- Nmin Soil Org Matt: the nitrogen mineralized from the soil organic matter,
- N-NO3 irrigat: the $N-NO_3^-$ contributed by the irrigation water,
- N-NH4 fert min: ammonium nitrogen contributed by the mineral fertilization,
- N-NO3 fert min: nitric nitrogen contributed by the mineral fertilization,
- N rainfall: nitrogen contributed by rainfall,
- Nmin manure: the N contributed from the mineralization of the organic N coming from the organic fertilization, and
- N2O_emission: nitrogen lost in the form of N_2O to the atmosphere in the nitrification and denitrification processes.

To the bottom of the dialog box it is included information regarding the dry matter production, both total and harvested, the nitrogen use efficiency (NUE) calculation, the N contained of crop residues, and the excess of nitrogen. The user can access to a more detailed recommendations in the N management, pressing the [Recommendation] button.

Additionally, the user can access to the information of the water balance activating the button [Water balance].

This table of the N balance can be exported to an MS Excel© format by clicking the [Export to excel] button. This tool only works if the Microsoft Office version installed is 2003 or higher. In case this tool does not work, all the rows and columns of the table can be selected, copied [Ctrl+C], and then go to an Excel worksheet and paste them [Ctrl+V]. Another tool the model has is the visualization of results from the nitrogen balance in graphical form. For this the [Plot] button must be pressed.

4.1.2.3 Nitrogen management Recommendation

The model show to the user a dialog box (Fig. 15) with some management recommendations based on three indicators; the nitrogen use efficiency, the excess of nitrogen applied and the potential loss of N uptake by the crop. In case of the nitrogen use efficiency was $< 50\%$ and the excess was > 80 kg N/ha, the recommendation is to reduce the fertilizer dose (thresholds set by the European panel of N experts, Oenema et al 2016). On the other hand, if the model simulates an extraction of N lower than 90%

of the potential extraction by the crop, a warning is activated so that the management of the nitrogen fertilizer should be reviewed, since at some month the crop has suffered a N deficiency. In this menu, the amount of N mineralized from the of organic matter application in the form of manure, slurry etc. is also calculated. In this regard, if this N mineralized by manures is greater than 170 kg N/ha (maximum limit for vulnerable areas in Europe), the model will provide you a warning to reduce the dose of organic fertilizer.

EVALUATION

	NUE (%)	CLASIFICACION	RECOMMENDATION
▶	> 100	High risk of soil loss fertility	Increase fertilizer and/or apply organic fertilizer
	90 - 100	Moderate risk of soil loss fertility	Increase fertilizer doses
	50 - 90	Balanced fertilization	Right fertilizer management
	< 50	High risk of nitrogen losses	Reduce fertilizer doses

N uptake efficiency =69.4 (%)
Recommended management: Right fertilizer management

	Excess of N (kg N/ha/year)	CLASIFICACION	RECOMMENDATION
	> 120	Very high	Reduce fertilizer dose and split better
	80 - 120	High	Reduce fertilizer dose
	50 - 80	Normal	Right fertilization
	20 - 50	Low	Look NUE recommendation
	< 20	Very low	Look NUE recommendation

*
Excess of N = 81.9 Kg N/ha/crop
Fertilizer management: Reduce fertilizer dose
Potential loss of N uptake = 18.7 %. Review fertilizer management

Dosis N in org. fert. = 105.06 Kg N/ha Cancel

Figure. 15. Dialog box with the main nitrogen management recommendations

4.1.2.1. Results of the water balance

In the nitrogen balance dialog box is included a button [water balance] to open a dialog box with the table of the main terms of the water monthly balance simulated by the model: rainfall, irrigation, reference evapotranspiration (ET_0), crop evapotranspiration (ET_c), and actual (ET_r) evapotranspiration, as well as drainage in mm units. Along with some indicators of irrigation and evapotranspiration efficiency that the model calculates for the months with irrigation (Fig. 16). Based in this table the user can modify the irrigation management to increase the water use efficiency saving water.

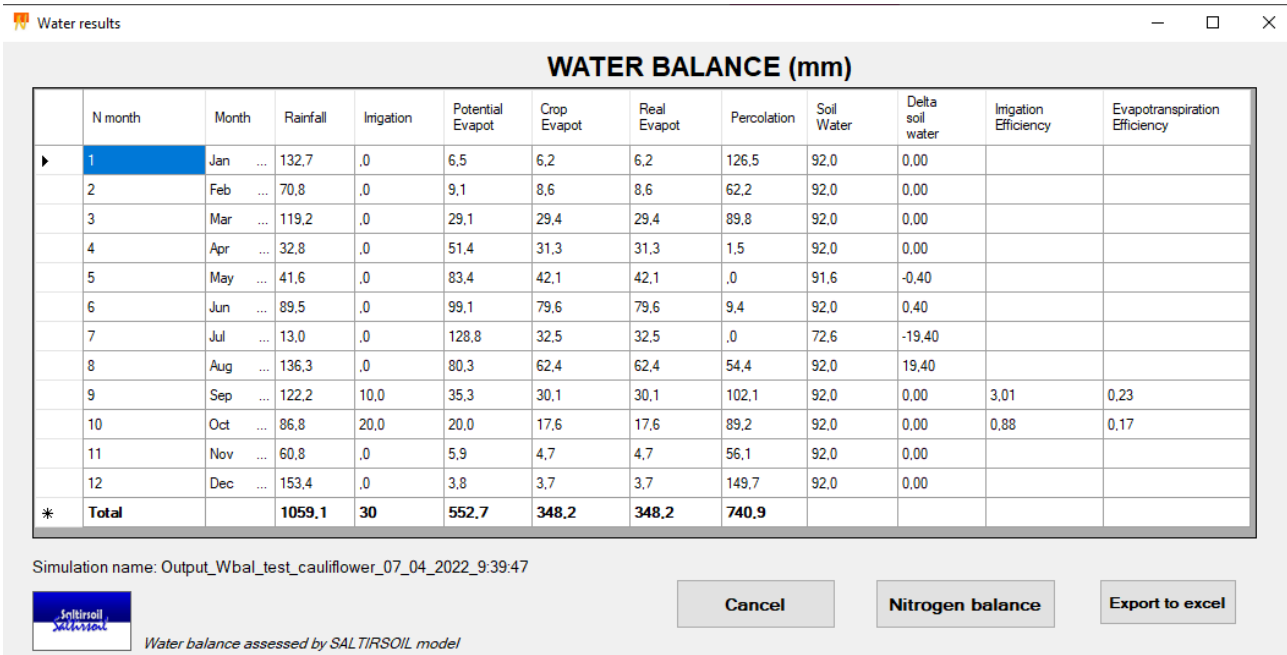


Figure 16. Table with the main terms of the simulated water balance

The columns of the water balance table contain the information that is described below:

- N month: month in number format from 1 to 12,
- Month: month in three-letter-abbreviated text format from Jan to Dec,
- Rainfall: cumulated rainfall (mm),
- Irrigation: irrigation rate (mm),
- Reference Evapot: The monthly reference evapotranspiration (mm)
- Crop Evapot: The montly crop evapotranspiration (mm),
- Real Evapot: actual evapotranspiration. If there is any month with water stress the actual evapotranspiration will be less than the crop evapotranspiration (mm),
- Percolation: water drainage or deep percolation away from the roots (mm),
- Soil Water: water content within the soil profile (mm),
- Delta soil water: soil water content increase regarding the previous month (mm),
- Irrigation Efficiency: irrigation efficiency calculated as actual evapotranspiration divided by irrigation (Irr. Eff. = Actual Evapotranspiration / Irrigation), and
- Evapotranspiration Efficiency: evapotranspiration efficiency calculated as actual evapotranspiration divided by irrigation plus rainfall (ET. Eff. = Actual Evapotranspiration/(Irrigation + Rainfall)).

4.2. Batch version

The NITIRSOIL model can be run to perform multiple simulations in a simple and easy way, one after another or by batches (“batch mode”). For this type of running, the data input and output is done on the “nitirsoil_batch.mdb” database itself. Another advantage

of this version of the model is that any user from outside the European countries included in the databases can generate their own input data tables and run the model so as to obtain the results of the nitrogen and water balance. In fact, this version has been used to validate the model against data observed in the field for 110 different scenarios (de Paz et al., 2022a).

4.2.1. Guidelines for data input

The user must enter the model input data directly on the various tables of the “nitirsoil_batch.mdb” database (Fig. 17). In order to ease the data input, this can be performed previously in an Excel workbook called “nitirsoil_batch_eng.xls” (Fig. 18). This book accompanies the model and contains the tables with the adequate structure. This way, the data from the workbook can be copied and pasted in the tables of the “nitirsoil_batch.mdb” or, directly, to import the tables to the database using the tools that exist for this regard in MS Access© (see Annex I). In any case, special care must be taken with the codes of the simulations, which must correspond to the codes in the several tables associated with the main table “Input_table_main”.

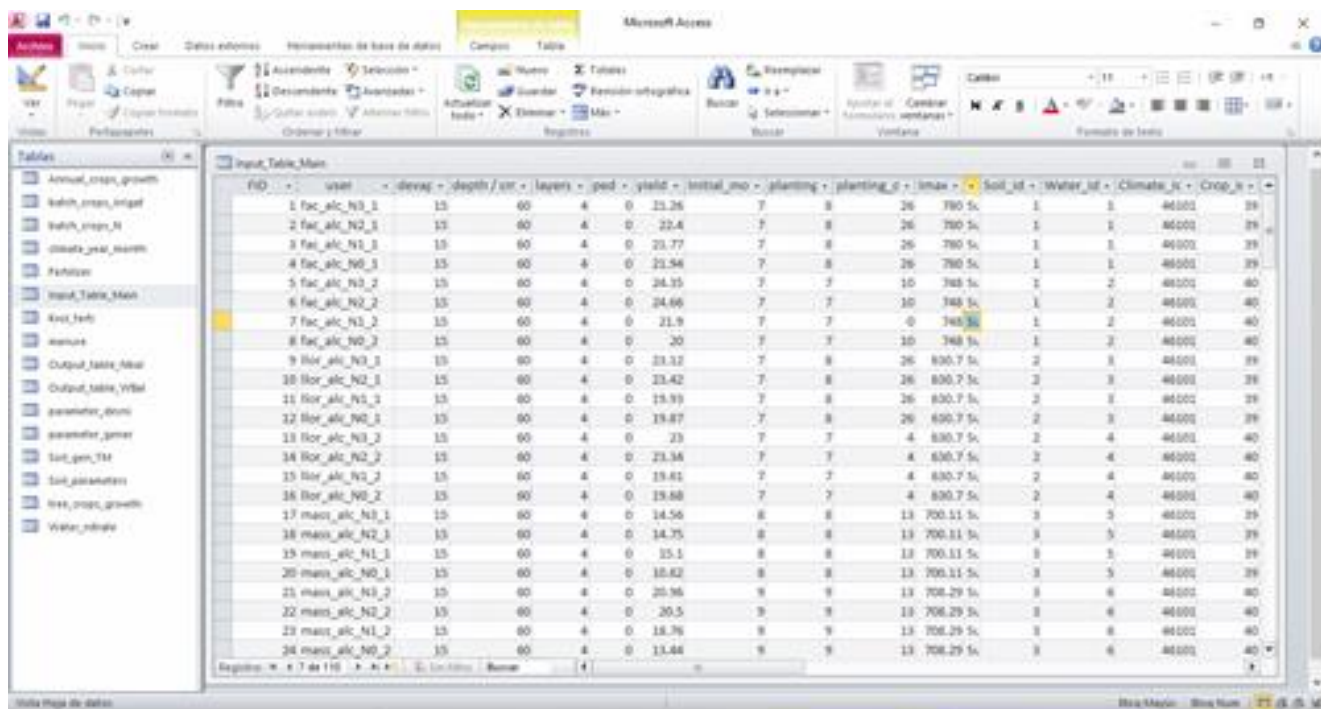


Figure 17. Look of the nitirsoil_batch.mdb database that manages the data input and output of the NITIRSOIL model in its batch version

ID	user	devap/cm	depth/cm	layers	pedotransfer	yield	initial_nsoth	planting_month	planting_day	Soil_id	Water_id	Climate_id	Crop_id	Irrigat_id	Year
4	2 Fac_alc_N2_1	15	60	4	0	22.4	7	8	26	1	1	46101	39	2	2001
5	3 Fac_alc_N1_1	15	60	4	0	21.77	7	8	26	1	1	46101	39	3	2001
6	4 Fac_alc_N0_1	15	60	4	0	21.94	7	8	26	1	1	46101	39	4	2001
7	5 Fac_alc_N3_2	15	60	4	0	24.35	7	7	10	1	2	46101	40	5	2002
8	6 Fac_alc_N2_2	15	60	4	0	24.66	7	7	10	1	2	46101	40	6	2002
9	7 Fac_alc_N1_2	15	60	4	0	21.9	7	7	0	1	2	46101	40	7	2002
10	8 Fac_alc_N0_2	15	60	4	0	20	7	7	10	1	2	46101	40	8	2002
11	9 Hor_alc_N3_1	15	60	4	0	23.12	7	8	26	2	3	46101	39	9	2001
12	10 Hor_alc_N2_1	15	60	4	0	23.42	7	8	26	2	3	46101	39	10	2001
13	11 Hor_alc_N1_1	15	60	4	0	19.93	7	8	26	2	3	46101	39	11	2001
14	12 Hor_alc_N0_1	15	60	4	0	19.87	7	8	26	2	3	46101	39	12	2001
15	13 Hor_alc_N3_2	15	60	4	0	23	7	7	4	2	4	46101	40	13	2002
16	14 Hor_alc_N2_2	15	60	4	0	23.34	7	7	4	2	4	46101	40	14	2002
17	15 Hor_alc_N1_2	15	60	4	0	19.61	7	7	4	2	4	46101	40	15	2002
18	16 Hor_alc_N0_2	15	60	4	0	19.68	7	7	4	2	4	46101	40	16	2002
19	17 mass_alc_N3_1	15	60	4	0	14.56	8	8	13	3	5	46101	39	17	2001
20	18 mass_alc_N2_1	15	60	4	0	14.75	8	8	13	3	5	46101	39	18	2001
21	19 mass_alc_N1_1	15	60	4	0	15.1	8	8	13	3	5	46101	39	19	2001
22	20 mass_alc_N0_1	15	60	4	0	10.62	8	8	13	3	5	46101	39	20	2001
23	21 mass_alc_N3_2	15	60	4	0	20.96	9	9	13	3	6	46101	40	21	2002
24	22 mass_alc_N2_2	15	60	4	0	20.5	9	9	13	3	6	46101	40	22	2002
25	23 mass_alc_N1_2	15	60	4	0	18.76	9	9	13	3	6	46101	40	23	2002
26	24 mass_alc_N0_2	15	60	4	0	13.44	9	9	13	3	6	46101	40	24	2002
27	25 ESP3_VH1_T4	15	60	4	0	43.871	2	2	23	4	7	319	22	25	2012
28	26 ESP3_VH1_T3	15	60	4	0	42.081	2	2	23	4	7	319	22	26	2012
29	27 ESP3_VH1_T2	15	60	4	0	40.905	2	2	23	4	7	319	22	27	2012
30	28 ESP3_VH1_T1	15	60	4	0	37.503	2	2	23	4	7	319	22	28	2012
31	29 ESP2_VH1_T4	15	60	4	0	38.7	2	2	18	5	8	319	22	29	2011
32	30 ESP2_VH1_T3	15	60	4	0	37.8	2	2	18	5	8	319	22	30	2011

Figure 18. Workbook nitirsoil_batch.xls where to enter the simulation data before its input in the nitirsoil_batch.mdb database

The input data the user has to enter in the model for the batch run are described below:

4.2.1.1. General data

In the “Input_table_main” (table 1) table the initial and general data of each simulation are entered. The tables where the different data the model requires to perform the simulations, as those of climate, soil, irrigation water, fertilizers, etc., are saved, are associated to this table. Each table record corresponds to one different simulation and their fields are:

- SIM: simulation code,
- User: user or simulation name,
- devap/cm: maximum soil depth down to which water can evaporate in cm,
- depth/cm: maximum simulation depth in cm,
- Layers: number of layers in which the soil is conceptually split, and which is 4 by default,
- pedotransfer: code to select the method through which the soil water holding capacity points, can be estimated with pedotransfer functions (code 1), or directly they are taken from the soil table (code 0), In this model version is just activated the option of direct input (code 0).
- yield: expected crop yield in t/ha,

- Initial_month: initial month of the simulation as an integer number from 1 to 12,
- planting_month: planting month as an integer number from 1 to 12,
- planting_day: day of the month when the crop is planted as an integer number,
- Soil_id: soil code that is related to the tables “Soil_gen_TM” and “Soil_parameters” where the soil data are saved,
- Water_id: water code that is related to the table “Water_nitrate” where the nitrate data in water are saved,
- Climate_id: climate code that is related to the table “Climate_year_month” where the climate data are saved,
- Crop_id: crop code that is related to the tables where the crop parameters, either annual “Annual_crops_growth” or woody “Tree_crops_growth”, are saved. If the code is between 0 and 200 it codifies for an annual crop, if it is over 200 it codifies for a woody crop.
- Irrigat_id: irrigation management code that is related with the table where the irrigation management data “Batch_crops_irrigat” are saved.
- Year: simulation year. This datum is used to retrieve the climate data saved in the “Climate_year_month” table, where the data is arranged according to weather station, year and month,
- Crop_duration: days the crop lasts from plantation until crop end,
- N-NO3_0-30: initial mineral nitrogen in the soil layer of 0-30 cm depth in kg_N/ha,
- N-NO3_30-60: initial mineral nitrogen in the soil layer of 30-60 cm depth in kg_N/ha,
- N-NO3_60-90: initial mineral nitrogen in the soil layer of 60-90 cm depth in kg_N/ha, and
- N-NO3_>90: initial mineral nitrogen in the soil layer below 90 cm depth in kg_N/ha.

Then, the initial soil water content, if the user has this information they can enter these data at different depths. So as for this, they must check the checkbox “Check_hvol” (see below). In case this checkbox is unchecked the model will estimate the initial soil water content. The soil water contents are:

- Hvol_0-30: percent of soil water content (%) in the 0-30 cm depth soil layer,
- Hvol_30-60: percent of soil water content (%) in the 30-60 cm depth soil layer,
- Hvol_60-90: percent of soil water content (%) in the 60-90 cm depth soil layer, and
- Hvol_>90: percent of soil water content (%) in the soil layer below 90 cm,

and the rest of the fields:

- Cropres_id: code of the crop from which the crop residues have been incorporated before the plantation of the crop to simulate, and which is related to the crop tables “Annual_crops_growth” and “Tree_crops_growth”. If the code is between 0 and 200 it codifies for an annual crop, and if it is over 200 it codifies for a woody crop,
- Yield_res: yield of the crop from which the residues have been incorporated in t/ha,
- mes_apl_res: month in which the residues have been incorporated. In general, it must match the initial simulation month or before this,

- Incorp_perc: percent of the residues produced by the crop that have been incorporated to the soil (%),
- Check_estres_hidric: checkbox. If it is checked the dry matter yield is diminished proportionally to the likely water stress, and if it is unchecked the yield is not diminished,
- Check_Hvol: checkbox to consider that the user enters the initial soil water content, or if it is unchecked, the model estimates the initial soil water content, and
- Drip_irrig: checkbox to tell the model that the irrigation is localized. If it is checked it means the irrigation is localized.

Table 1. Table “Input_table_main” where the input data to the NITIRSOIL model in the *batch* version are saved

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	FID	user	devap_cm	depth_cm	layers	pedotransfer	yield	Initial_month	Initial month for the simulation	ing_day	Soil_id	Water_id	Climate_id	Crop_id	Irrigat_id	FertiN_id
2	1	fac_alc_N3_1	15	60	4	0	19,58	7		26	1	1	46101	39	1	1
3	2	fac_alc_N2_1	15	60	4	0	20,63	7		26	1	1	46101	39	2	2
4	3	fac_alc_N1_1	15	60	4	0	20,58	7		26	1	1	46101	39	3	3
5	4	fac_alc_N0_1	15	60	4	0	19,82	7		26	1	1	46101	39	4	4
6	5	fac_alc_N3_2	15	60	4	0	24,35	7		22	1	2	46101	40	5	5
7	6	fac_alc_N2_2	15	60	4	0	24,66	7		22	1	2	46101	40	6	6
8	7	fac_alc_N1_2	15	60	4	0	21,90	7		22	1	2	46101	40	7	7
9	8	fac_alc_N0_2	15	60	4	0	20,00	7		22	1	2	46101	40	8	8
10	9	llor_alc_N3_1	15	60	4	0	23,80	7		26	2	3	46101	39	9	9
11	10	llor_alc_N2_1	15	60	4	0	23,33	7		26	2	3	46101	39	10	10
12	11	llor_alc_N1_1	15	60	4	0	20,57	7		26	2	3	46101	39	11	11
13	12	llor_alc_N0_1	15	60	4	0	20,16	7		26	2	3	46101	39	12	12
14	13	llor_alc_N3_2	15	60	4	0	22,40	7		4	2	4	46101	40	13	13
15	14	llor_alc_N2_2	15	60	4	0	23,29	7		4	2	4	46101	40	14	14
16	15	llor_alc_N1_2	15	60	4	0	19,74	7		4	2	4	46101	40	15	15
17	16	llor_alc_N0_2	15	60	4	0	17,79	7		4	2	4	46101	40	16	16
18	17	mass_alc_N3_1	15	60	4	0	14,56	8		13	3	5	46101	39	17	17
19	18	mass_alc_N2_1	15	60	4	0	14,74	8		13	3	5	46101	39	18	18
20	19	mass_alc_N1_1	15	60	4	0	15,11	8		13	3	5	46101	39	19	19
21	20	mass_alc_N0_1	15	60	4	0	10,61	8		13	3	5	46101	39	20	20
22	21	mass_alc_N3_2	15	60	4	0	20,97	9		13	3	6	46101	40	21	21
23	22	mass_alc_N2_2	15	60	4	0	20,51	9		13	3	6	46101	40	22	22
24	23	mass_alc_N1_2	15	60	4	0	18,75	9		13	3	6	46101	40	23	23
25	24	mass_alc_N0_2	15	60	4	0	13,45	9		13	3	6	46101	40	24	24

From the “Input_table_main” table, the model takes the information saved in the other tables in the “nitirsoil_batch.mdb” database in order to generate the dataset that is required by the model run and perform the simulation. In color red are represented the fields required by the model from each of the tables are indicated. The other columns are purely informative.

The codes and relationships established between this initial table and the other tables are indicated in Fig. 19.

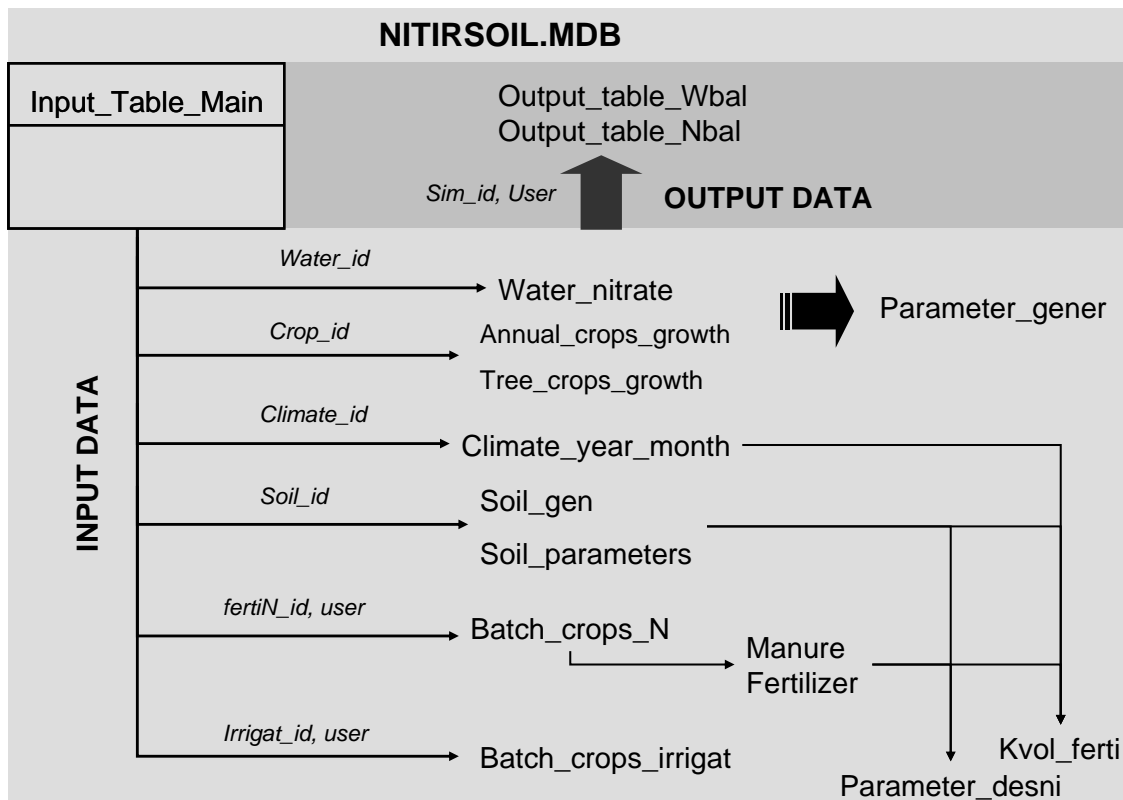


Figure 19. Scheme of the input, run, and output of the NITIRSOIL model in *batch* version

4.2.1.2. Irrigation water quality

In the “Water_nitrate” table the nitrate concentration data in the irrigation water are entered. The fields the user must fill in this table are (Table 2):

- water_id: identification number code of the irrigation water for each simulation. This code must match the “water_id” table from the initial “Input_table_main” table, and
- [Nitrate (mg/l)]: nitrate concentration in the irrigation water (mg/l).

Table 2. “Water_nitrate” table where the irrigation water quality data are saved

	A	G	J
1	water_id	Nitrate (mg/l)	
2	number	number	
3	1	95.83	
4	2	39.1	
5	3	91	
6	4	31.68	
7	5	59.6	
8	6	33	
9	7	9.2	
10	8	9.2	
11	9	5.7	
12	10	106	
13	11	19.2	
14	12	19.2	
15	13	17.35	
16	14	14.7	
17	15	18.5	
18	16	22.45	
19	17	22.45	
20	18	22.45	
21	19	33.11	
22	20	20	
23	21	10	
24	22	63.09	

Table 3. “Soil_gen” table where the soil hydrologic group data are saved

	A	K
1	soil_id	GH
2	1	B
3	2	B
4	3	B
5	4	C
6	5	B
7	6	B
8	7	B
9	8	B
10	9	B
11	10	B
12	11	C
13	12	B
14	13	C
15	14	C
16	15	C
17	16	C

4.2.1.3. Climate

In the “Climate_year_month” table the monthly climate data from the various weather stations are saved. This table is the same used in the *windows* version.

Monthly climate information is stored in the [climate_year_month] table. In this version of the model, the user must enter the specific climatic data of his area following the structure of "climate_year_month" (Table 4). The fields of this table that the batch version needs are:

- Climate_id: numerical identification code that must correspond to the climate_id included in the input_table_main table,
- Year: year of the simulation. You must have complete information of the years that the crop development occupies
- Month: month in numeric format from 1 to 12,
- Tmean: monthly mean temperature in °C,
- Rain: monthly precipitation in mm,
- Rainy days: number of days per month with rain above 0.1 mm, and
- ETo: reference evapotranspiration for each month in mm.

Tabla 4. Tabla “climate_year_month” donde se guardan los datos climáticos mensuales distribuidos por estaciones meteorológicas

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	climate_id	Climate code linked to the climate_id code of the Input_main_table		Month	Tmean	Tmax	Tmin	Rain	Days of rainfall	ETo					
2	46101			1	7,58	13,14	2,02	0,00	0	36,00					
3	46101	Moncada IVIA	1992	2	9,03	15,85	2,21	58,40	4	54,20					
4	46101	Moncada IVIA	1992	3	13,23	18,76	7,71	5,90	3	109,40					
5	46101	Moncada IVIA	1992	4	14,68	20,88	8,48	0,00	0	134,10					
6	46101	Moncada IVIA	1992	5	18,92	24,77	13,06	78,80	1	155,80					
7	46101	Moncada IVIA	1992	6	18,87	24,35	13,38	68,70	7	154,90					
8	46101	Moncada IVIA	1992	7	22,65	28,97	16,34	0,00	0	210,40					
9	46101	Moncada IVIA	1992	8	24,72	30,76	18,68	0,00	0	206,60					
10	46101	Moncada IVIA	1992	9	21,12	26,10	16,13	73,70	3	124,70					
11	46101	Moncada IVIA	1992	10	17,35	23,02	11,69	66,50	8	83,80					
12	46101	Moncada IVIA	1992	11	14,67	22,13	7,20	0,00	0	71,80					
13	46101	Moncada IVIA	1992	12	11,19	15,98	6,39	57,20	1	55,90					
14	46101	Moncada IVIA	1993	1	9,20	15,70	2,28	6,60	1	51,40					
15	46101	Moncada IVIA	1993	2	9,41	14,38	4,45	90,10	10	62,10					
16	46101	Moncada IVIA	1993	3	10,59	16,81	4,37	27,00	3	98,10					
17	46101	Moncada IVIA	1993	4	14,13	20,72	7,53	63,20	4	147,30					
18	46101	Moncada IVIA	1993	5	17,75	23,40	12,09	24,60	9	172,40					

4.2.1.4. Soil

The soil data os datos de suelos se introducen en dos tablas. are entered in two tables. In the table “soil_gen” (Table 3) the hydrologic group is saved, and in the table “soil_parameters” the soil parameters so are arranged by depths. The “Soil_gen” table is very similar to the one used for the *windows* version but without the information regarding the geographical location of the soil data. As a consequence, in the “Soil_gen” table the fields to use are only:

- soil_id: soil type code, and
- GH: hydrologic group, which is classified into A, B, C, and D as a function of its hydrologic characteristics (Table 5).

Table 5. Soil and drainage characteristics for each hydrologic Group

Hydrologic group	Soil and drainage characteristics
A	Sandy texture and very good drainage
B	Loam texture and good drainage
C	Clay-loam texture and moderate drainage
D	Clay and/or silt texture and restricted drainage

Besides, in the “Soil_parameters” table stores the soil parameters differentiated by depths. The columns of this table for this batch version of the model are:

- Soil_id: soil code that is related to the previous table "soil_gen", in relation from 1 to n, and that must correspond to the "soil_id" code included in the table "Input_table_main" where the general information of the simulation is stored.
- Top_cm: depth of the upper limit of the soil layer in cm,
- Bottom_cm: depth of the lower limit of the soil layer in cm,
- BD_gr_cm3: bulk density of the soil layer in g/cm³,
- H_saturation: saturation volumetric humidity of the soil layer expressed in 1/u,
- Sand: percentage of sand-sized particles ($\emptyset > 0.050$ mm) of the soil layer according to the USDA textural classification,
- Clay: percentage of clay-sized soil particles ($\emptyset < 0.002$ mm) of the soil layer according to the USDA textural classification,
- pH: pH value of the soil layer,
- OM: percentage of organic matter in the soil layer,
- C_N: carbon/nitrogen ratio of the soil layer, if this information is not available, the model takes 10 by default,
- FC_cm_cm: volumetric humidity of the soil layer at the field capacity point in cm³/cm³,
- WP_cm_cm: volumetric humidity of the soil layer at the permanent wilting point in cm³/cm³,
- Carbonates_percent: percentage of calcium carbonate equivalent of the soil layer. This parameter is only necessary if you want to use the pedotransfer functions to calculate the field capacity and the permanent wilting point, and
- CF: percentage of coarse elements of the soil layer.

Table 6. -Table "Soil_parameters" where the data of physicochemical characteristics of the soils by depths are stored

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	soil_id	Soil code. Same the soil_id of input_table_main	Top_cm	bottom_cm	BD_gr_cm3	H_saturation	sand	silt	Clay	texture_USDA	ph	OM	C_N	FC_cm_cm	WP_cm_cm	Carbonates	CF
2	1	al	0	30	1,45	0,420	46,0	32,0	22,0	Loam	7,90	1,37	10,00	0,270	0,120	20,80	0,00
3	1	al	30	60	1,63	0,380	23,0	42,0	35,0	Clay Loam	7,80	1,03	10,00	0,330	0,230	20,00	0,00
4	1	alcachofa_facundo	60	90	1,72	0,350	39,0	33,0	28,0	Clay Loam	7,90	0,51	10,00	0,310	0,200	20,00	0,00
5	2	alcachofa_lloris	0	30	1,48	0,410	52,0	29,0	19,0	loam	8,00	1,88	10,00	0,240	0,100	20,80	0,00
6	2	alcachofa_lloris	30	60	1,64	0,380	26,0	42,0	32,0	Clay Loam	8,10	1,03	10,00	0,320	0,220	20,00	0,00
7	2	alcachofa_lloris	60	90	1,67	0,360	39,0	34,0	27,0	loam	8,10	0,51	10,00	0,300	0,190	20,00	0,00
8	3	alcachofa_massanasa	0	30	1,41	0,430	52,0	30,0	18,0	Clay-loam	8,00	1,20	10,00	0,270	0,100	20,00	0,00
9	3	alcachofa_massanasa	30	60	1,69	0,400	28,0	42,0	30,0	Clay-loam	7,80	1,03	10,00	0,310	0,210	20,00	0,00
10	3	alcachofa_massanasa	60	90	1,67	0,360	38,0	34,0	28,0	Clay-loam	7,90	0,68	10,00	0,300	0,190	20,00	0,00
11	4	VILLENA_Puntal3	0	30	1,36	0,498	19,7	41,5	38,8	Silty Clay Loam	8,40	2,50	10,00	0,383	0,238	20,00	0,00
12	4	VILLENA_Puntal3	30	60	1,41	0,505	15,0	40,4	44,6	Silty Clay	8,50	1,70	10,00	0,407	0,268	20,00	0,00
13	5	VILLENA_Puntal2	0	15	1,36	0,453	30,4	43,6	26,0	Loam	8,24	1,66	10,00	0,320	0,165	20,00	0,00
14	5	VILLENA_Puntal2	15	30	1,36	0,445	32,4	41,4	26,3	Loam	8,30	1,48	10,00	0,311	0,165	20,00	0,00
15	5	VILLENA_Puntal2	30	60	1,41	0,433	35,5	35,7	28,8	Clay Loam	8,40	0,93	10,00	0,314	0,179	20,00	0,00
16	6	VILLENA_Puntal1	0	30	1,41	0,472	21,0	44,7	34,4	Clay Loam	8,30	1,49	10,00	0,361	0,210	20,00	0,00
17	6	VILLENA_Puntal1	30	60	1,48	0,481	11,5	52,0	36,5	Silty Clay Loam	8,35	1,12	10,00	0,372	0,221	20,00	0,00
18	6	VILLENA_Puntal1	60	90	1,64	0,427	38,6	30,5	30,9	Clay Loam	8,27	0,58	10,00	0,306	0,188	20,00	0,00
19	7	Espinosa_1	0	30	1,54	0,425	52,0	28,2	19,9	Loam	8,05	1,65	10,00	0,350	0,120	20,00	0,00
20	7	Espinosa_1	30	60	1,70	0,441	30,6	39,1	30,3	Clay Loam	8,27	1,01	10,00	0,350	0,210	20,00	0,00
21	7	Espinosa_1	60	90	1,78	0,420	41,0	31,0	28,1	Clay Loam	8,37	0,64	10,00	0,320	0,190	20,00	0,00
22	8	Espinosa_2	0	30	1,47	0,420	63,7	21,4	14,9	Sandy Loam	8,20	1,55	10,00	0,350	0,080	20,00	0,00
23	8	Espinosa_2	30	60	1,57	0,447	28,8	40,5	30,7	Clay Loam	8,30	1,04	10,00	0,380	0,210	20,00	0,00

4.2.1.5. Irrigation management

In the "Batch_crops_irrigat" table the irrigation data management must be entered for each simulation (Table 7), where each identification code (sim_id, user) is unique for each irrigation management. These codes must correspond to the ones entered by the user in the "Input_table_main" table. The fields in this table are:

- Sim_id: relational code with the "Input_table_main" table,
- User: user or simulation name. It is related to the "Input_table_main" table,
- I..._mm: irrigation rate per month in mm (Ijan_mm, Ifeb_mm, Imar_mm, Iapr_mm, Imay_mm, Ijun_mm, Ijul_mm, Iaug_mm, Isep_mm, Ioct_mm, Inov_mm, Idec_mm), and
- If..._day: number of irrigation days per month (Ijan_day, Ifeb_day, Imar_day, Iapr_day, Imay_day, Ijun_day, Ijul_day, Iaug_day, Isep_day, Ioct_day, Inov_day, Idec_day).

Table 7. "Batch_crops_irrigat" table where the irrigation management data are saved for each simulation

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Irrigat_id	user	ljan_mm	ifeb_mm	imar_mm	lapr_mm	lmay_mm	ljun_mm	Total irrigation dose (mm or l/m2) in june	lsep_mm	loct_mm	lnov_mm	ldec_mm	lfjan_day	lffeb_day	
2	1	fac_alc_N3_1	0	60	115	62	0	0	203	220	35	0	86	0	0	1
3	2	fac_alc_N2_1	0	60	115	62	0	0	203	220	35	0	86	0	0	1
4	3	fac_alc_N1_1	0	60	115	62	0	0	203	220	35	0	86	0	0	1
5	4	fac_alc_N0_1	0	60	115	62	0	0	203	220	35	0	86	0	0	1
6	5	fac_alc_N3_2	150	35	30	87	0	0	0	101	70	80	138	56	3	1
7	6	fac_alc_N2_2	150	35	30	87	0	0	0	101	70	80	138	56	3	1
8	7	fac_alc_N1_2	150	35	30	87	0	0	0	101	70	80	138	56	3	1
9	8	fac_alc_N0_2	150	35	30	87	0	0	0	101	70	80	138	56	3	1
10	9	lfor_alc_N3_1	0	54	102	57	0	0	143	167	27	81	0	0	0	1
11	10	lfor_alc_N2_1	0	54	102	57	0	0	143	167	27	81	0	0	0	1
12	11	lfor_alc_N1_1	0	54	102	57	0	0	143	167	27	81	0	0	0	1
13	12	lfor_alc_N0_1	0	54	102	57	0	0	143	167	27	81	0	0	0	1
14	13	lfor_alc_N3_2	96	41	80	69	0	0	0	99	93	132	0	2	1	1
15	14	lfor_alc_N2_2	96	41	80	69	0	0	0	99	93	132	0	2	1	1
16	15	lfor_alc_N1_2	96	41	80	69	0	0	0	99	93	132	0	2	1	1
17	16	lfor_alc_N0_2	96	41	80	69	0	0	0	99	93	132	0	2	1	1
18	17	mass_alc_N3_1	0	121	114	71	0	29	128	169	133	91	0	0	0	2
19	18	mass_alc_N2_1	0	121	114	71	0	29	128	169	133	91	0	0	0	2
20	19	mass_alc_N1_1	0	121	114	71	0	29	128	169	133	91	0	0	0	2
21	20	mass_alc_N0_1	0	121	114	71	0	29	128	169	133	91	0	0	0	2
22	21	mass_alc_N3_2	86	119	86	0	0	0	0	107	115	99	96	1	2	2
23	22	mass_alc_N2_2	86	119	86	0	0	0	0	107	115	99	96	1	2	2
24	23	mass_alc_N1_2	86	119	86	0	0	0	0	107	115	99	96	1	2	2
25	24	mass_alc_N0_2	86	119	86	0	0	0	0	107	115	99	96	1	2	2

4.2.1.6. Nitrogen fertilization management

In the “Batch_crops_N” table the user must enter the data regarding the mineral and organic nitrogen fertilization (Table 8). This way, 12 records with the input data of mineral and organic fertilizers per month correspond to each simulation. The table has the following fields:

- FertiN_id: relational code with the “Input_table_main” table,
- User: user or simulation name. It is related with the “Input_table_main” table,
- Month: month in which the fertilizer is applied in number format from 1 to 12,
- Dosis_fm: monthly rate of the fertilizer in its trade formulation in kg/ha,
- N-NO3: nitric N rate applied with the mineral fertilizer in kg_N/ha,
- N-NH4: ammonium N rate applied with the mineral fertilizer in kg_N/ha,
- Faplic_fm: way of application of the mineral fertilizer (surface, incorporated, drip, injected),
- Code_tipo_apl_fm: number that codifies for the way of application of the mineral fertilizer according to Table 9,
- Code_fo: number that codifies for the type of organic fertilizer. It is related with the “manure” table where the characteristics of each organic fertilizer are saved,
- Dosis_fo: application rate of each organic fertilizer in t/ha,
- Code_tipo_apl_fo: number that codifies for the way of application of the organic fertilizer. They are the same as in the case of the mineral fertilizer (Table 20),

Table 8. “Batch_crops_N” table where the mineral and organic nitrogen fertilizer data are saved

FertiN_id	user	crop	month	code_fert	fertilizer_name	Dosis_fm	N-NO3	N-NH4	Tipo_fm	Faplic_fm	Code_tipo_apl_fm	tipo_forg	Faplic_forg	Code
1	1 fac_alc_N3_1	alcachofa_1	1											
2	1 fac_alc_N3_1	alcachofa_1	2	7	Nitrato amonico	128	22,5	22,5	solid	incorporated	2			
3	1 fac_alc_N3_1	alcachofa_1	3											
4	1 fac_alc_N3_1	alcachofa_1	4											
5	1 fac_alc_N3_1	alcachofa_1	5											
6	1 fac_alc_N3_1	alcachofa_1	6											
7	1 fac_alc_N3_1	alcachofa_1	7											
8	1 fac_alc_N3_1	alcachofa_1	8											
9	1 fac_alc_N3_1	alcachofa_1	9											
10	1 fac_alc_N3_1	alcachofa_1	10	7	Nitrato amonico	180	30	30	solid	incorporated	2			
11	1 fac_alc_N3_1	alcachofa_1	11											
12	1 fac_alc_N3_1	alcachofa_1	12											
13	2 fac_alc_N2_1	alcachofa_1	1											
14	2 fac_alc_N2_1	alcachofa_1	2											
15	2 fac_alc_N2_1	alcachofa_1	3											
16	2 fac_alc_N2_1	alcachofa_1	4											
17	2 fac_alc_N2_1	alcachofa_1	5											
18	2 fac_alc_N2_1	alcachofa_1	6											
19	2 fac_alc_N2_1	alcachofa_1	7											

Table 9. Codes of the types of fertilizer application

Code	Type of fertilizer application
1	Surface
2	Incorporated
3	Drip irrigation
4	Injected

4.2.2. Model run and results

For running the model, one must simply look for the nitirsoil_batch.exe application and click on such executable file. In addition to the input data tables, the nitirsoil_batch.mdb also contains the output data tables. This database should be located in the subdirectory .../database/ where the executable is installed. These must not be erased nor its structure modified since the model recognizes them and fills them with the results of the new simulations. In each run, the model does erase the contents of the output tables "Output_table_Nbal" and "Output_table_Wbal" before filling them with the results of the new simulation. Specifically, for each combination of the "sim_id" plus "User" codes the model runs one simulation and generates, as a consequence, 12 records with the results that correspond to each of the 12 months of the year of water balance in the "Output_table_Wbal", and of nitrogen balance in the "Output_table_Nbal" table.

4.2.2.1. Results of the water balance

In the "Output_table_Wbal" table the results from the water balance for all the simulations performed by means of the model run in *batch* mode are saved (Table 10). In order to visualize the results of the water balance the nitirsoil_batch.mdb database must be opened and this table looked for. Its structure is similar to the one generated by the model in *windows* mode, but in this case all the results are saved in only one table. The fields are:

- Sim_id: simulation code,
- User: user or simulation name,
- R/mm: monthly rainfall in mm,
- I/mm: monthly irrigation rate in mm,

- ETo/mm: monthly reference evapotranspiration in mm,
- ETc/mm: monthly crop evapotranspiration in mm,
- ETa/nmm: monthly actual evapotranspiration in mm. It considers if there is enough water in the soil to evapotranspire,
- D/mm: monthly drainage in mm,
- Month: month in three-letter-abbreviated text format,
- Mes: month in number format from 1 to 12, and
- Soil_water: soil water content at the end of the month in the simulation depth in mm.

Table 10. “Output_table_Wbal” table where the results of the water balance simulated by the NITIRSOIL model in *batch* mode are saved

	A	B	C	D	E	F	G	H	I	J	K
1	Sim_id	user	month_number	R / mm	Monthly rainfall (mm)	ETc / mm	ETa / mm	D / mm	SOIL WATER / mm	month	
2	1	fac_alc_N3_1	1	22,60	0,00	30,08	24,64	24,53	0,00	178,07	Jan
3	1	fac_alc_N3_1	2	0,00	60,00	58,02	44,00	44,00	14,07	180,00	Feb
4	1	fac_alc_N3_1	3	30,10	115,00	74,26	66,76	66,76	78,34	180,00	Mar
5	1	fac_alc_N3_1	4	68,00	62,00	94,67	81,43	81,43	48,57	180,00	Apr
6	1	fac_alc_N3_1	5	96,10	0,00	122,34	90,43	90,43	5,67	180,00	May
7	1	fac_alc_N3_1	6	35,30	0,00	154,82	40,35	40,35	0,00	174,95	Jun
8	1	fac_alc_N3_1	7	0,00	203,00	163,97	13,79	13,79	184,16	180,00	Jul
9	1	fac_alc_N3_1	8	1,80	220,00	142,19	56,11	56,11	165,69	180,00	Aug
10	1	fac_alc_N3_1	9	167,30	35,00	91,39	66,76	66,76	135,54	180,00	Sep
11	1	fac_alc_N3_1	10	36,20	0,00	71,97	51,63	50,14	0,00	166,06	Oct
12	1	fac_alc_N3_1	11	57,30	86,00	37,74	30,84	30,84	98,51	180,00	Nov
13	1	fac_alc_N3_1	12	43,90	0,00	27,74	24,95	24,95	18,95	180,00	Dec
14	10	llor_alc_N2_1	1	22,60	0,00	30,08	24,64	24,52	0,00	166,08	Jan
15	10	llor_alc_N2_1	2	0,00	53,90	58,02	44,00	44,00	7,98	168,00	Feb
16	10	llor_alc_N2_1	3	30,10	101,50	74,26	66,76	66,76	64,84	168,00	Mar
17	10	llor_alc_N2_1	4	68,00	57,20	94,67	81,43	81,43	43,77	168,00	Apr
18	10	llor_alc_N2_1	5	96,10	0,00	122,34	90,43	90,43	5,67	168,00	May
19	10	llor_alc_N2_1	6	35,30	0,00	154,82	40,35	40,35	0,00	162,95	Jun
20	10	llor_alc_N2_1	7	0,00	143,00	163,97	13,79	13,79	124,16	168,00	Jul
21	10	llor_alc_N2_1	8	1,80	167,40	142,19	56,11	56,11	113,09	168,00	Aug
22	10	llor_alc_N2_1	9	167,30	26,50	91,39	66,76	66,76	127,04	168,00	Sep
23	10	llor_alc_N2_1	10	36,20	81,00	71,97	54,89	54,89	62,31	168,00	Oct
24	10	llor_alc_N2_1	11	57,30	0,00	37,74	29,42	29,42	27,88	168,00	Nov
25	10	llor_alc_N2_1	12	43,90	0,00	27,74	24,95	24,95	18,95	168,00	Dec
26	100	SAND_BUR_ES	1	49,80	0,00	30,49	7,69	7,69	42,11	217,99	Jan
27	100	SAND_RIIR_ES	2	40,10	0,00	53,99	35,18	35,18	4,92	217,99	Feb

4.2.2.2. Results of the nitrogen balance

In the “Output_table_Nbal” table the nitrogen balance results are saved for all the simulations performed by means of the model run in *batch* mode (Table 11). In order to visualize the nitrogen balance results, the nitirsoil_batch.mdb database must be open and this table looked for. Its structure is similar to the one generated by the model run in *windows* mode, but in this case all the results are saved in only one table. The fields are:

- Sim_id: identification simulation code. This code is taken from the “Input_table_main” table,
- User: user or simulation name. This code is taken from the “Input_table_main” table,
- Month: simulation month in number format from 1 to 12,
- Ndemand: crop nitrogen potential demand in kg N/ha,
- Nuptake: crop nitrogen actual uptake simulated by the model in kg N/ha,
- Ndenitrif: nitrogen lost as N₂ by denitrification in kg N/ha,
- Nvolat: N-NH₄⁺ lost as NH₃ by volatilization in kg N/ha,

- Nleached: $N-NO_3^-$ lost by leaching in kg N/ha,
- Drain: percolated water below the rooting depth in mm,
- Nmin_ini: soil mineral nitrogen content within the simulation depth the first day of the month,
- Nmin_end: soil mineral nitrogen content within the simulation depth at the end of the month,
- N-NO3input: $N-NO_3^-$ input as the addition of the contributions from the mineral and organic fertilizers, the nitrification, the irrigation water and the rainfall,
- NO3nitrif: produced $N-NO_3^-$ by the nitrification process,
- NminSOM: mineral nitrogen contributed from the mineralization of the soil organic matter,
- N_NO3_irrig: applied $N-NO_3^-$ with the irrigation water,
- N_NH4fm: applied $N-NH_4^+$ with the mineral fertilization,
- N_NO3fm: applied $N-NO_3^-$ with the mineral fertilization,
- N prec: contributed $N-NO_3^-$ by the rainfall,
- Nmin_man: mineral nitrogen contributed from the mineralization of the applied manure,
- Total Dry Matter: crop total dry matter production in t/ha,
- Dry matter yield: crop harvested dry matter production in t/ha,
- NN2O: emission of N_2O to the atmosphere in kg N/ha,
- N residue: nitrogen content of the crop residues at the crop end in kg N/ha,
- N apl Resid: mineral nitrogen contributed from the mineralization of the residues of the previous crop during the development of the crop to simulate in kg N/ha, and
- Order: consecutive order of the simulated months in which the crop is growing.

Table 11. “Output_table_Nbal” table with the results of N balance simulated by the NITIRSOIL model in *batch* version

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Sim_id	user	month	Ndemand	N crop potential demand (kg N/ha)	volat	Nleached	Drain	Nmin_ini	Nmin_end	N_NO3input	N_NO3nitrif	NminSOM	N_NO3irrig	N_NH4fm	N_NO3fm	Nprec	Nmin_m	
2	1	fac_alc_N3_1	7	0,00		0,57	66,52	184,16	296,00	276,85	54,69	10,73	11,31	43,96	0,00	0,00	0,00		
3	1	fac_alc_N3_1	8	1,79	1,79	17,63	0,69	65,83	165,69	276,85	252,42	60,82	13,16	13,88	47,65	0,00	0,00	0,01	
4	1	fac_alc_N3_1	9	12,90	12,90	7,75	0,58	71,00	135,54	252,42	180,13	19,36	10,99	11,58	7,58	0,00	0,00	0,79	
5	1	fac_alc_N3_1	10	27,35	27,35	2,49	0,12	0,00	0,00	180,13	190,22	39,93	9,76	9,88	0,00	30,00	30,00	0,17	
6	1	fac_alc_N3_1	11	33,53	30,49	1,06	0,16	96,05	98,51	190,22	86,12	23,88	4,98	5,25	18,63	0,00	0,00	0,27	
7	1	fac_alc_N3_1	12	34,94	27,33	0,28	0,09	18,58	18,95	86,12	44,25	4,31	4,11	4,32	0,00	0,00	0,00	0,21	
8	1	fac_alc_N3_1	1	35,22	11,11	0,00	0,00	0,00	0,00	44,25	34,97	3,98	3,88	4,08	0,00	0,00	0,00	0,11	
9	1	fac_alc_N3_1	2	34,49	17,25	0,30	0,03	7,99	14,07	34,97	48,60	39,17	3,67	3,72	12,99	22,50	22,50	0,00	
10	1	fac_alc_N3_1	3	27,58	22,06	2,28	0,31	16,70	78,34	48,60	38,43	30,86	5,81	6,12	24,91	0,00	0,00	0,14	
11	1	fac_alc_N3_1	4	24,22	20,19	2,16	0,34	2,59	48,57	38,43	29,97	20,30	6,55	6,90	13,43	0,00	0,00	0,32	
12	1	fac_alc_N3_1	5	16,49	10,64	1,11	0,17	0,17	5,67	29,97	26,42	8,37	7,91	8,33	0,00	0,00	0,00	0,46	
13	1	fac_alc_N3_1	6	0,00	0,00	1,21	0,53	0,00	0,00	26,42	35,35	10,14	9,97	10,51	0,00	0,00	0,00	0,17	
14	2	fac_alc_N2_1	7	0,00	0,00	5,58	0,57	45,49	184,16	202,00	205,62	54,69	10,73	11,31	43,96	0,00	0,00	0,00	
15	2	fac_alc_N2_1	8	1,86	1,86	15,28	0,69	45,01	165,69	205,62	204,29	60,82	13,16	13,88	47,65	0,00	0,00	0,01	
16	2	fac_alc_N2_1	9	13,40	13,40	7,46	0,58	48,38	135,54	204,29	154,41	19,36	10,99	11,58	7,58	0,00	0,00	0,79	
17	2	fac_alc_N2_1	10	28,41	18,82	0,58	0,20	0,00	0,00	154,41	144,56	9,55	9,38	9,88	0,00	0,00	0,00	0,17	
18	2	fac_alc_N2_1	11	34,83	30,14	0,00	0,00	76,83	98,51	144,56	61,47	23,88	4,98	5,25	18,63	0,00	0,00	0,27	
19	2	fac_alc_N2_1	12	36,30	14,41	0,00	0,00	16,72	18,95	61,47	34,65	4,31	4,11	4,32	0,00	0,00	0,00	0,21	
20	2	fac_alc_N2_1	1	36,58	7,64	0,00	0,00	0,00	0,00	34,65	31,00	3,98	3,88	4,08	0,00	0,00	0,00	0,11	
21	2	fac_alc_N2_1	2	35,84	17,92	0,03	0,11	6,95	14,07	31,00	22,63	16,53	3,53	3,72	12,99	0,00	0,00	0,00	

5. Data required by the model

The NITIRSOIL model has been designed to require the minimum number of data and parameters in order to achieve optimal applicability and thus be able to be used by the maximum number of users (Fig. 1). In order to boost this simple operation, a database of climate, soil, irrigation water, crop, etc., has been implemented along with the model.

5.1. General model data

The general data the model requires to be run are:

- Name of the simulation (character string),
- Simulation initial month (from January to December),
- In the case of being in the Valencian Community (Spain), province and municipality where the plot is located. This option is not included in the batch version,
- Simulation depth (cm),
- Number of layers in which the user wants the soil profile to be conceptually split to carry out the simulation and which is taken as 4 by default,
- Depth down to which the soil is thought to be able to evaporate water (cm),
- For the soil water holding characteristic points a choice between the following:
 - to assess them by using pedotransfer functions implemented within the model, or
 - to enter them as experimental data, and
- For the dry matter production, a choice between the following:
 - to activate the application of a water stress factor, or
 - to not activate it.

5.2. Climate data

The main climate data the model requires are:

- Monthly average temperature (°C),
- Monthly reference evapotranspiration (mm),
- Monthly rainfall (mm),
- Monthly number of days with rainfall (ud).

5.3. Crop management data

These data must be directly entered by the user using the menus that have been designed.

- Crop:
 - Crop species: artichoke, tomato, cauliflower, citrus, etc.,
 - Plantation date: plantation day and month,
 - Crop length in days, and

- Yield in t/ha.
- Fertilization:
 - Mineral:
 - Application month,
 - Dose (kg fertilizer/ha),
 - Type of fertilizer: ammonium nitrate, 15-15-15, ammonium sulphate, etc.,
 - Contents of N-NO_3^- and N-NH_4^+ applied with the fertilization,
 - In the *windows* version, it is directly calculated from the dose and type of fertilizer,
 - In the *batch* version it must be entered as datum.
 - Type of application: surface, incorporated, drip, injected.

The NITIRSOIL model requires the total amount of mineral fertilizer each month

- Organic:
 - Application month,
 - Dose (t/ha),
 - Type of manure: chicken droppings, pig-slurry, cow-slurry, etc.,
 - Type of application: surface, incorporation, drip, injected,

The NITIRSOIL model allows only one application throughout the cropping season.

- Irrigation:
 - Month of the irrigation application,
 - Irrigation rate per month (l/m^2),
 - Number of irrigation days per month,
 - Irrigation technique: surface, furrows, drip.
- Crop residue:
 - Crop species: artichoke, tomato, cauliflower, etc.
 - Yield of the crop that generates the residue (t/ha).
 - Percentage of residue incorporation to the soil (%). Which percentage of the non-harvested plant part is left on the field and incorporated into the soil.

5.4. Soil data

The NITIRSOIL model requires for its calculations the following data arranged per soil layer:

- pH,
- Soil organic matter percent (OM),
- C/N ratio, which, in case this datum is not available it is taken 10 by default,
- Texture, weight percent of sand and clay according to the USDA particle-size classes (%),
- Bulk density (g/cm^3),
- Coarse fragments percentage ($\text{Ø} > 2 \text{ mm}$) (%),
- Calcium carbonate equivalent percent (%), this datum is only required for using the pedotransfer function that calculates the soil water content at field capacity.
- Soil water content at field capacity and at the permanent wilting point (1/ud). In case this information is not available the model is furnished with pedotransfer functions for their calculation from texture, calcium carbonate equivalent, and organic matter contents,
- Hydrologic group. Soils can be classified into 4 hydrologic groups called A, B, C, and D depending on their soil and drainage characteristics (Table 5),
- Initial soil mineral nitrogen content for the 0-30, 30-60, 60-90, and below 90 cm depth intervals,
- Initial soil water content for the 0-30, 30-60, 60-90, and below 90 cm depth intervals. In case these data are not entered, the model simulates the initial conditions from the climate and irrigation data.

5.5. Nitrate concentration in the irrigation water

The model uses the nitrate concentration in the irrigation water to calculate the amount of nitrogen contributed to the crop by this way. This value must be entered in units of mg/L of nitrate. Only one water quality is allowed in each simulation. The nitrate concentration cannot be changed throughout the crop development. Therefore, in case several water qualities are used in the exploitation, an average nitrate value should be entered.

6. Internal parameters

The internal parameters of the model are those that regulate the processes that occur in the N dynamics such as volatilization, denitrification, etc., as well as all the parameters that define the plant N uptake, etc. Both versions of the model, *windows* and *batch*, share the structure and content of the tables where these parameters are housed in the *nitirsoil.mdb* and *nitirsoil_batch.mdb* databases. The parameters can be easily modified by accessing the tables where they are stored, as well as, for the windows version through the menus that have been designed for the graphical user interface.

6.1. General parameters

The general parameters that regulate some of the transformations that occur in the nitrogen dynamics define the model internal working. Processes such as mineralization, denitrification, nitrification, leaching, etc., are regulated by means of coefficients that

are stored in the “parameter_gener” table (Table 12) in the “nitirsoil.mdb” database. These coefficients are described below.

- Komr_slow: rate coefficient for the soil organic matter of slow mineralization. By default, it is 0.00037 ud/day,
- Komr_fast: rate coefficient of the soil organic matter of fast mineralization. By default, it is 0.0059 ud/day,
- CN_fast: carbon-to-nitrogen ratio in the soil organic matter of fast mineralization rate. By default, it is 17,
- N_no_pool: percent of soil organic N in the pool of fast mineralization rate. By default, it is 10%,
- Kcres_manure: rate coefficient for the mineralization of manure. By default, it is 0.03 ud/day,
- Ppres_manure: carbon-to-dry-matter ratio for manure. By default, it is 0.37 (1/u),
- Kcres_veg: rate coefficient for the mineralization of the crop residues. By default it is 0.06 ud/day,
- PCres_vegetal: carbon-to-dry-matter ratio for the crop residues. By default, it is 0.6 (1/u),
- Knitrif: nitrification coefficient. By default, it is 33.6 kg_N/ha,
- Klix: nitrate leaching coefficient. It is factor related to the soil nitrate leaching efficiency. By default, it is 0.8,
- Kvol_soil: soil ammonium volatilization coefficient in the months when there are no contributions of organic or ammonium fertilizers. By default, it is 0.05,
- KN2Onitrif: N₂O emission coefficient from nitrification. By default, it is 0.002, and
- KN2Odesn: N₂O emission coefficient from denitrification. By default, it is 0.2.

Table 12. Table “parameter_gener” of the NITIRSOIL model where the various internal parameters of the model are saved

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
1	ID	Komr_slow	Komr_fast	CN_fast	N_no_pool	Kcres_manure	Kcres_veg	Kcres_oth	Ppres_manure	Ppres_veg	Ppres_oth	Knitrif	Kinh_nitrif	Klix	Kvol_soil	KN2O_nitr	KN2O_dn	
2	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	
3		1	0.00037	0.0059	17	5	0.03	0.06	0.003	0.37	0.6	0.3	33.6	1	0.80	0.05	0.00	0.20

In the windows version, a dialog box entitled “General model parameters” (Fig. 130), where the user can change the coefficients that the model uses for the N dynamics simulation, has been designed. This dialog box can be accessed from the drop-down menu [Database access → Model parameters]. The user can change all the general parameters and then, by pressing the [Update] button the “parameter_gener” table is updated in the “nitirsoil.mdb” database while, simultaneously, the original table is preserved by renaming to “parameter_gener_” plus the date and time when the updating was performed (e.g.: parameter_gener_03_12_2012_14:26:34).

This way the original tables are kept, so as in case one wants to retrieve the original table, this can be done by simply opening the “nitirsoil.mdb” database and changing the name “parameter_gener_03_12_2012_14:26:34” by “parameter_gener”.

Another way to modify these parameters is by directly editing the “parameter_gener” table in the “nitirsoil.mdb” database. In fact, in the model batch version there have not

been included tools to help edit these values and hence this should be done by directly editing the table.

Soil organic matter Mineralization	
Kmin slow (1/day)	0.00037
Kmin fast (1/day)	0.0059
C/N fast mineralization	17
N-pool fast mineralization (%)	5

Wastes and residues mineralization			
Kmin animal waste (1/day)	0.03	Carbon in animal waste dm (1/u)	0.37
Kmin vegetal residues (1/day)	0.06	Carbon in veg. residue dm (1/u)	0.6
Kmin other matters (1/day)	0.003	Carbon in other matters dm (1/u)	0.3

K nitrification (Kg N/ha/day)	33.6	K volatilization soil (1/u)	0.05
K inhibition (1/u)	1	K N2O emission nitrific (1/u)	0.002
K leaching	1.5	K N2O emission desnitr. (1/u)	0.2

Figure 20. Dialog box for the editing and updating of the model table of general parameters

6.2. Volatilization coefficients

The nitrogen losses by ammonium volatilization to the atmosphere mainly occur from the application of ammonium and organic fertilizers. This process is regulated through the volatilization coefficient, which depends on the soil pH, the fertilizer type (ammonium sulphate, urea, etc.), the application method (surface, incorporated, etc.) and the type of month according to its humidity when it is applied (humid, sub-humid or dry), in addition to the soil cation exchange capacity. Therefore, the basal volatilization coefficients proposed by Meisinger and Randall (1991), which depend on the first four properties, have been adapted and they are housed in the “Kvol_ferti” table with the following fields (Table 13).

- code: identification code of the volatilization coefficient,
- N-NH₄: content of N-NH₄⁺ in the fertilizer (%).
- Fertilizer: name of the fertilizer. In case it is organic it is simply called organic,
- Application: method of fertilizer application. The options are surface, incorporated, drip and injected,
- pH: soil pH value. There are two options: “< 7” or “> 7”. On the basis of the soil pH one option or another is chosen,
- humid_month: volatilization coefficient for a humid month (%). A humid month is that in which the addition of rainfall plus irrigation days is over 15 (Table 25),
- Subhumid_month: volatilization coefficient for a sub-humid month (%). A sub-humid month is that in which the addition of rainfall plus irrigation days is between 10 and 15 (Table 25),
- Dry_month: volatilization coefficient for a dry month (%). A dry month is that in which the addition of rainfall plus irrigation days is under 10 (Table 25),

In order to modify the values of the volatilization coefficients, the user should access the NITIRSOIL databases and edit the table “Kvol_ferti” and change these values directly, both in the *windows* and *batch* versions.

Table 13. Table “Kvol_ferti” where the basal volatilization coefficients are saved as a function of the type of fertilizer, way of fertilization, soil pH and type of month depending on its humidity

1	A	B	C	D	E	F	G	H	I	J	K
2	code	N_NH4	Fertilizante	Fertilizer	Forma_aplicacion	Code_apl	Application	pH	mes_humedo	mes_subhumedo	mes_seco
3	autonumber	number	text	text	text	number	text	text	number	number	number
3	1	46	Urea	Urea	Superficie	1	Surface	>7	10.0	16.0	21.0
4	2	46	Urea	Urea	Incorporado	2	Incorporated	>7	5.0	6.0	7.0
5	3	46	Urea	Urea	Goteo	3	Drip	>7	7.0	12.0	15.0
6	4	46	Urea	Urea	Inyectado	4	Injected	>7	1.0	2.0	3.0
7	5	20	Sulfato amonico	Ammonium sulfate	Superficie	1	Surface	>7	20.0	25.0	35.0
8	6	20	Sulfato amonico	Ammonium sulfate	Incorporado	2	Incorporated	>7	5.0	10.0	15.0
9	7	20	Sulfato amonico	Ammonium sulfate	Goteo	3	Drip	>7	10.0	18.0	25.0
10	8	20	Sulfato amonico	Ammonium sulfate	Inyectado	4	Injected	>7	2.0	3.0	4.0
11	9	17	Nitrato Amonico	Ammonium Nitrate	Superficie	1	Surface	>7	10.0	13.0	15.0
12	10	17	Nitrato Amonico	Ammonium Nitrate	Incorporado	2	Incorporated	>7	2.0	3.0	4.0
13	11	17	Nitrato Amonico	Ammonium Nitrate	Goteo	3	Drip	>7	7.0	5.0	12.0
14	12	17	Nitrato Amonico	Ammonium Nitrate	Inyectado	4	Injected	>7	1.0	2.0	3.0
15	13	5	Otro fertilizante	Any fertilizer	Superficie	1	Surface	>7	13.3	17.6	21.6
16	14	5	Otro fertilizante	Any fertilizer	Incorporado	2	Incorporated	>7	1.0	2.0	3.0
17	15	5	Otro fertilizante	Any fertilizer	Goteo	3	Drip	>7	8.0	11.6	15.0
18	16	5	Otro fertilizante	Any fertilizer	Inyectado	4	Injected	>7	0.5	0.8	1.0
19	17	46	Urea	Urea	Superficie	1	Surface	<7	2.5	10.0	15.0
20	18	46	Urea	Urea	Incorporado	2	Incorporated	<7	1.3	3.8	5.0
21	19	46	Urea	Urea	Goteo	3	Drip	<7	1.8	7.5	10.7
22	20	46	Urea	Urea	Inyectado	4	Injected	<7	0.3	1.3	2.1
23	21	20	Sulfato amonico	Ammonium sulfate	Superficie	1	Surface	<7	5.0	15.6	25.0
24	22	20	Sulfato amonico	Ammonium sulfate	Incorporado	2	Incorporated	<7	1.3	6.3	10.7
25	23	20	Sulfato amonico	Ammonium sulfate	Goteo	3	Drip	<7	2.5	11.3	17.9
26	24	20	Sulfato amonico	Ammonium sulfate	Inyectado	4	Injected	<7	0.5	1.9	2.9
27	25	17	Nitrato Amonico	Ammonium Nitrate	Superficie	1	Surface	<7	2.5	8.1	10.7
28	26	17	Nitrato Amonico	Ammonium Nitrate	Incorporado	2	Incorporated	<7	0.5	1.9	2.9
29	27	17	Nitrato Amonico	Ammonium Nitrate	Goteo	3	Drip	<7	1.8	3.1	8.6
30	28	17	Nitrato Amonico	Ammonium Nitrate	Inyectado	4	Injected	<7	0.3	1.3	2.1
31	29	5	Otro fertilizante	Any fertilizer	Superficie	1	Surface	<7	3.3	11.0	15.4
32	30	5	Otro fertilizante	Any fertilizer	Incorporado	2	Incorporated	<7	0.3	1.3	2.1
33	31	5	Otro fertilizante	Any fertilizer	Goteo	3	Drip	<7	2.0	7.3	10.7
34	32	5	Otro fertilizante	Any fertilizer	Inyectado	4	Injected	<7	0.1	0.5	0.7
35	33	0	Organico	Organic	Superficie	1	Surface	>7	10.0	15.0	25.0
36	34	0	Organico	Organic	Incorporado	2	Incorporated	>7	5.0	5.0	5.0
37	35	0	Organico	Organic	Goteo	3	Drip	>7	7.0	12.0	15.0
38	36	0	Organico	Organic	Inyectado	4	Injected	>7	1.0	2.0	3.0
39	37	0	Organico	Organic	Superficie	1	Surface	<7	5.0	7.0	10.0
40	38	0	Organico	Organic	Incorporado	2	Incorporated	<7	1.0	1.0	1.0
41	39	0	Organico	Organic	Goteo	3	Drip	<7	3.0	5.0	8.0
42	40	0	Organico	Organic	Inyectado	4	Injected	<7	0.0	0.0	0.0
43											
44											
45											
46											

6.3. Denitrification coefficients

The denitrification is a process by means of which the soil NO_3^- is reduced up to N_2O and N_2 , and it is thus lost to the atmosphere. The algorithm the NITIRSOIL model uses to represent this process is regulated by means of the denitrification coefficient. This coefficient changes mainly as a function of the type of soil (hydrologic group), the soil organic matter content in the surface layer (0-30 cm), the irrigation method, and the application of organic fertilizers. The denitrification coefficients the model uses are stored in the “parameter_desni” table (Table 14) with the following fields:

- ID: autonumber code,
- SOM: soil organic matter content. It may be: < 2%, 2-5%, > 5%,
- A: daily denitrification coefficient for a soil from the hydrologic group A (1/u/day),
- B: daily denitrification coefficient for a soil from the hydrologic group B (1/u/day),
- C: daily denitrification coefficient for a soil from the hydrologic group C (1/u/day),
- D: daily denitrification coefficient for a soil from the hydrologic group D (1/u/day),

From the calculation of this coefficient, the model increases its value in 20% if an organic fertilization occurs, and in 10 % if the irrigation method is trickle.

In order to change these values, the user must access the NITIRSOIL databases and edit the “parameter_desni” table both for the *windows* and the *batch* versions.

Table 14. Structure of the “parameter_desni” table where the denitrification coefficients are saved as a function of the hydrologic group and the soil organic matter content

	A	B	C	D	E	F
1	ID	SOM	A	B	C	D
2	number	number	number	number	number	number
3	1	2	0.03	0.04	0.06	0.1
4	2	5	0.04	0.06	0.1	0.15
5	3	90	0.06	0.1	0.15	0.25

6.4. Crop parameters

The parameters that define the characteristics of the dry matter production, as well as the water and nitrogen crop uptake are found in two tables, one for the annual crops and another for the woody crops (multiannual).

6.4.1. Annual crops

The parameters that define the annual crops are in the “Annual_crops_growth” table (Table 15), which presents the following fields:

- ID: autonumber code,
- Crop_id: crop identification code,
- Crop: crop name,
- Potential_yield_t_ha: potential crop fresh yield at the season end in t/ha,
- DM: dry-to-fresh matter index (1/u). Dry-to-fresh harvested matter ratio,
- HI: harvest index. Harvested-to-total dry matter ratio,
- C1: coefficient “a” in the nitrogen dilution curve throughout the crop development (Equation 36), which is used to calculate the potential crop N uptake,
- C2: coefficient “b” in the nitrogen dilution curve throughout the crop development (Equation 36), which is used to calculate the potential crop N uptake,
- Kcb...: basal crop coefficient for each of the four development stages of annual crops (Fig. 21):
 - Kcbi: initial,
 - Kcbd: development,
 - Kcbm: maturing, and
 - Kcbs: senescence,
- L...: relative length of each of the four development stages of annual crops expressed as a ratio to the total season length:
 - Li_Ltotal: initial,
 - Ld_Ltotal: development,
 - Lm_Ltotal: maturing, and

- Ls_Ltotal: senescence,
- Ltotal: length of the crop growing season in days,
- rd_cm: maximum rooting depth in cm,
- Shaded_area_max: maximum canopy covered area (1/u).

And additionally, the following parameters which are needed in case the incorporation of crop residues is considered:

- Moisture_perc: crop water content in percentage,
- N_percent_dm: crop nitrogen content on a dry matter basis.

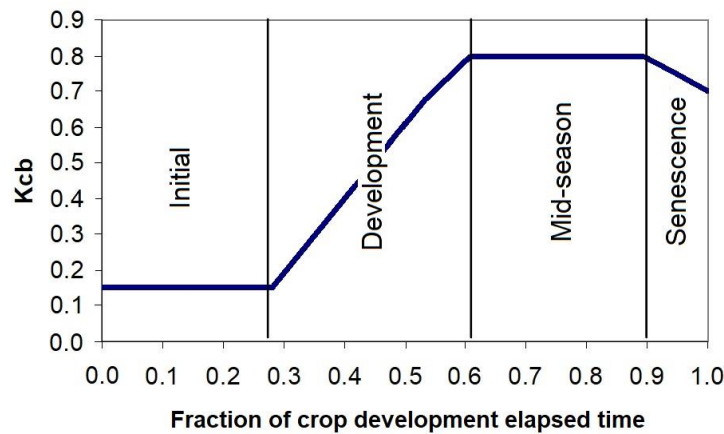


Figure 21. Basal crop coefficients (Kcb) for the various stages of crop development of annual crops

Table 15. Table “Annual_Crops_Growth” where the parameters that define the development and water and nitrogen uptake of annual crops are saved

	B	C	E	F	G	H	J	K	L	M	N	O	P	Q	S	T	U	V
1	Crop_id	CROP	DM	C1	HI	C2	Kcbl	Kcbd	Kcbm	Kcbs	Lj_Ltotal	Ld_Ltotal	Lm_Ltotal	Ls_Ltotal	shaded_area_max	rd_cm	Moisture_perc	N_percent_dm
2	number	text	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number
3	1	Broad_beans	0.136	4.50	0.48	0.27	0.15	0.63	1.10	0.68	0.158	0.263	0.368	0.211	0.75	60	87	3
4	2	Brussels_Sprouts	0.200	4.90	0.60	0.10	0.15	0.55	0.95	0.85	0.240	0.360	0.300	0.100	0.75	45	91	4.4
5	3	Dutch_White_Cabbage	0.093	4.77	0.65	0.10	0.15	0.55	0.95	0.85	0.263	0.368	0.263	0.105	0.8	45	91	2.8
6	4	Cabbage_Summer	0.078	4.39	0.75	0.15	0.15	0.55	0.95	0.85	0.263	0.368	0.263	0.105	0.8	45	91	2.8
7	5	Cabbage_Wint/Spring	0.120	4.39	0.54	0.15	0.15	0.55	0.95	0.85	0.263	0.368	0.263	0.105	0.8	45	91	2.8
8	6	Broccoli	0.120	4.50	0.28	0.40	0.15	0.50	1.40	0.85	0.100	0.170	0.520	0.210	0.75	45	90	3
9	7	Carrot	0.101	2.60	0.69	0.22	0.15	0.55	0.95	0.90	0.188	0.250	0.375	0.188	0.75	45	88	1.5
10	8	Cauliflower	0.064	5.35	0.25	0.21	0.3	0.63	0.95	0.90	0.240	0.250	0.300	0.210	0.75	40	91	3.5
11	9	Chinese_Cabbage	0.037	4.70	0.47	0.11	0.15	0.53	1.13	0.90	0.160	0.330	0.500	0.010	0.98	60	93.7	4.01
12	10	French_beans	0.122	4.50	0.49	0.40	0.15	0.58	1.00	0.90	0.222	0.333	0.333	0.111	0.75	60	87	3
13	11	Leeks	0.110	3.50	1.00	0.10	0.15	0.52	0.90	0.90	0.100	0.170	0.520	0.210	0.75	50	87	3
14	12	Lettuce_Butterhead	0.036	4.30	0.62	0.06	0.15	0.53	0.90	0.90	0.181	0.282	0.270	0.260	0.74	45	95	4.1
15	13	Lettuce_Crisp	0.040	4.51	0.80	0.11	0.15	0.53	0.90	0.90	0.181	0.282	0.270	0.260	0.74	45	95	4.1
16	14	Maize_grain	0.800	1.30	0.80	0.26	0.15	0.65	1.15	0.50	0.200	0.267	0.333	0.200	0.85	150	70	1.25
17	15	Onion	0.078	2.40	0.98	0.12	0.15	0.55	0.95	0.80	0.100	0.167	0.467	0.267	0.5	35	92.3	1.59
18	16	Parsnip	0.170	2.50	0.95	0.20	0.15	0.58	1.00	0.85	0.170	0.250	0.420	0.170	0.5	40	82	1.5
19	17	Peas	0.180	3.95	0.25	0.20	0.15	0.63	1.10	1.08	0.200	0.300	0.350	0.150	0.75	75	80	4.2
20	18	Potato_Early	0.220	3.70	0.84	0.20	0.15	0.63	1.10	0.88	0.192	0.231	0.346	0.231	0.65	50	75	1.6
21	19	Potato_Late	0.226	5.01	0.95	0.42	0.15	0.63	1.10	0.88	0.210	0.240	0.340	0.210	0.65	60	75	1.6
22	20	Radish	0.056	3.09	0.50	0.13	0.15	0.50	0.85	0.80	0.143	0.286	0.429	0.143	0.55	40	88	1.5
23	21	Red_Beet	0.140		0.76													
24	22	Spinach	0.083	4.10	0.61	0.13	0.15	0.53	1.00	1.00	0.300	0.400	0.290	0.010	1	45	89	4.7
25	23	Sugar_Beet	0.230	3.69	0.70	0.27	0.15	0.65	1.15	0.83	0.196	0.326	0.348	0.130	0.55	80	82	2.1

In the *windows* version, a dialog box (Fig. 22), where the user can modify the parameters that the NITIRSOIL model uses in its simulations, has been designed. It can be accessed from the drop-down menu [Database access → Crop → Annual]. In this dialog box the user can simply visualize the parameters for each of the annual crops that have been included in the “Annual_crops_growth” table, as well as, delete, modify parameters and add new crops.

In order to visualize and select a crop to modify, the list (“CROP”) must be unfolded. Once a crop has been selected, in the group “Edit Options” the action the user wants to perform must be selected:

- Show: the data are shown but they cannot be edited,
- Edit: the data are shown and they can be edited and modified,
- Remove: the selected crop can be deleted,
- Add new: add a new crop to the table of annual crops,

For the action chosen by the user to take effect, the [OK] button must subsequently be pressed.

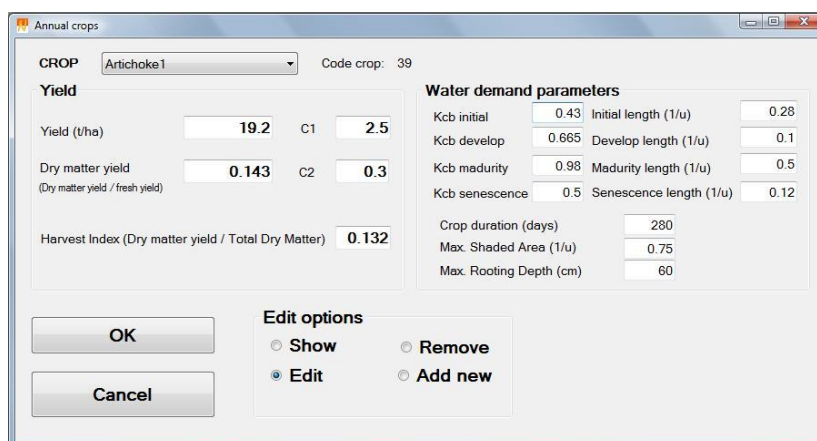


Figure 22. Dialog box for the visualization, edition, deletion and addition of parameters of annual crops

In case the *batch* version is used, the user can modify the parameters of the annual crops by accessing to the database and editing the “Annual_crops_growth” table.

6.4.2. Multiannual crops

The parameters defining the woody crops (multiannual) are in the “Tree_crops_growth” table (Table 16), which presents the following fields:

- ID: autonumber code,
- Crop_id: identification code, in the case of woody crops the code_id is over 200,
- Crop: crop name,
- Potential_yield_t_ha: potential crop fresh yield at the season end in t/ha,
- DM: dry-to-fresh matter index (1/u) calculated as the dry-to-fresh harvested matter ratio and expressed in 1/ud,
- HI: harvest index calculated as the harvested-to-total dry matter ratio and expressed in 1/ud,
- C1: coefficient “a” in the nitrogen dilution curve throughout the crop development (Equation 36), which is used to calculate the potential crop N uptake,
- C2: coefficient “b” in the nitrogen dilution curve throughout the crop development (Equation 36), which is used to calculate the potential crop N uptake,

- Kcb...: basal crop coefficients for each of the year months:

- Kcbjan: basal coefficient for January,
- Kcbfeb: basal coefficient for February,
- Kcbmar: basal coefficient for March,
- Kcbapr: basal coefficient for April,
- Kcbmay: basal coefficient for May,
- Kcbjun: basal coefficient for June,
- Kcbjul: basal coefficient for July,
- Kcbaug: basal coefficient for August,
- Kcbsep: basal coefficient for September,
- Kcboct: basal coefficient for October,
- Kcbnov: basal coefficient for November,
- Kcbdec: basal coefficient for December,

- rd_cm: maximum rooting depth in cm,

- Shaded_area_max: maximum canopy covered area expressed in 1/u,

Table 16. Table “Tree_crops_growth” where the parameters defining the development, and water and nitrogen uptake of the woody crops (multiannual) are saved

	B	C	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	Crop_id	crop	DM	HI	CI	C2	rd_cm	Kcbjan	Kcbfeb	Kcbmar	Kcbapr	Kcbmay	Kcbjun	Kcbjul	Kcbaug	Kcbsep	Kcboct	Kcbnov	Kcbdec	Shaded_area_max
2	number	text	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number	number
3	201	Orange > 15 year, surface irrig.	0.200	0.49	1.68	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
4	202	Orange 5-15 year, surface irrig.	0.200	0.47	1.68	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
5	203	Orange < 5 year, surface irrig.	0.200	0.10	1.68	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
6	204	Orange > 15 year, drip irrig.	0.200	0.64	1.68	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
7	205	Orange 5-15 year, drip irrig.	0.200	0.64	1.68	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
8	206	Orange < 5 year, drip irrig.	0.200	0.64	1.68	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
9	207	Mandarine > 15 year, surface irrig.	0.190	0.79	2.83	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
10	208	Mandarine 5-15 year, surface irrig.	0.190	0.79	2.83	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
11	209	Mandarine < 5 year, surface irrig.	0.190	0.79	2.83	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
12	210	Mandarine > 15 year, drip irrig.	0.190	0.79	2.83	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
13	211	Mandarine 5-15 year, drip irrig.	0.190	0.79	2.83	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
14	212	Mandarine < 5 year, drip irrig.	0.190	0.79	2.83	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
15	213	Lemon > 15 year, surface irrig.	0.180	0.49	1.60	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
16	214	Lemon 5-15 year, surface irrig.	0.180	0.47	1.60	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
17	215	Lemon < 5 year, surface irrig.	0.180	0.10	1.60	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
18	216	Lemon > 15 year, drip irrig.	0.180	0.49	1.60	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
19	217	Lemon 5-15 year, drip irrig.	0.180	0.47	1.60	0.015	60	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.49
20	218	Lemon < 5 year, drip irrig.	0.180	0.10	1.60	0.015	40	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.14
21	219	Grape fruit	0.200	0.49	1.60	0.015	80	0.63	0.62	0.63	0.59	0.52	0.59	0.65	0.75	0.70	0.80	0.69	0.60	0.81
22	220	Fig tree					80	0.00	0.15	0.16	0.45	0.58	0.63	0.65	0.65	0.53	0.22	0.00	0.70	
23	221	Apple tree					80	0.00	0.00	0.22	0.39	0.54	0.66	0.68	0.68	0.66	0.57	0.00	0.00	0.70
24	222	Peach tree	0.104	0.57			80	0.00	0.00	0.36	0.43	0.50	0.64	0.86	0.57	0.57	0.57	0.00	0.00	0.70
25	223	Medlar tree					90	0.59	0.65	0.63	0.55	0.46	0.16	0.16	0.42	0.55	0.67	0.73	0.60	0.60

Similar to the previous menu for the edition of the annual crops, a dialog box (Fig. 23) has been designed for the user to be able to modify the crop parameters the NITIRSOIL model requires in the simulation of woody crops. This menu can be accessed through the general drop-down menu [Database access → Crop → Perennial]. In this dialog box the user can simply visualize the values for each of the multiannual crops that have been included in the “Tree_crops_growth” table, or either, delete, modify parameters or add new crops.

In order to visualize and select the crop to modify, the drop-down list “CROP” must be unfolded. Once a crop has been selected, in the group “Edit Options” the user can select the action they want to perform:

- Show: the crop data are shown but they cannot be edited,
- Edit: the crop data are shown and they can be edited and modified,
- Remove: the selected crop can be deleted,
- Add new: add a new crop to the table of multiannual crops,

For the action chosen by the user to take effect, the [OK] button must subsequently be pressed.

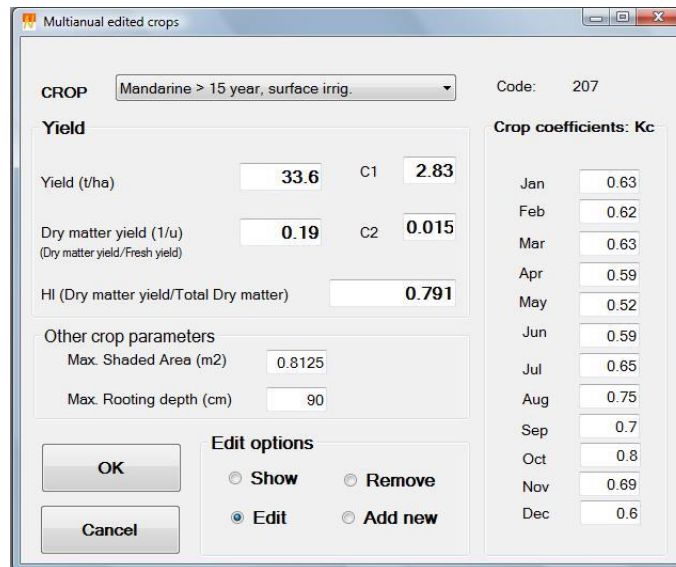


Figure 23. Dialog box for the edition of the woody crops parameters

In case the *batch* version is used, the user can modify the woody crops parameters by accessing the `nitirsoil_batch.mdb` database, and directly editing the “Tree_crops_growth” table.

7. Model tables

These tables store the information regarding the data on climate, soil, and nitrate content of the irrigation water, which the model in both versions, *windows* and *batch*, uses to perform the simulations. These tables are for supporting the user so that they has the information more accessible through the graphical interface. All these tables are saved with a specific format and structure in the model databases as is detailed below.

7.1. Irrigation water quality data

In the [Water_nitrate] table the data on the nitrate concentration of the irrigation water is saved (Table 17). In the version that is distributed this table contains data from the Valencian Community (Spain). In case the user does not use any of the waters included in this table, they will be able to enter this datum in the input menu of the irrigation water for the *windows* version, or build a new table for the *batch* version.

In the [Water_nitrate] table it is saved, in addition to the nitrate concentration, the information regarding the location of the waters (province and municipality), if it is surface or groundwater, and also the sample taking date. The fields in this table are:

water_id: identification code of the water,

Name: name of the well, irrigation channel, river, etc., where the water comes from,

Nitrate (mg/l): nitrate concentration in the water in mg/l,

Date: date when the sample was taken for analysis (date/time),

source: origin of the water: well, irrigation channel, spring, desalination plant, etc.,

For the batch version, only the fields [water_id] and [Nitrate (mg/l)] are required.

Table 17. Table “Water_nitrate” where the nitrate content in the irrigation waters is saved

	A	B	C	D	E	F	G	H	I
1	water_id	Municipio	CODE_PROVINCIA	codigo Municipio	Name	Date	Nitrate (mg/l)	Source	Procedencia
2	number	text	text	text	text	data	number	text	text
3	232	Xàtiva	46	46145	VELLES	06-03-07	79.0	Well	Pozo
4	232	Xàtiva	46	46145	VELLES	13-09-06	72.0	Well	Pozo
5	168	Canals	46	46081	COMANDANTA	12-09-06	26.0	Well	Pozo
6	168	Canals	46	46081	COMANDANTA	15-03-07	30.0	Well	Pozo
7	210	Aspe	03	03019	Nº 6	30-05-07	14.0	Well	Pozo
8	210	Aspe	03	03019	Nº 6	17-10-06	9.0	Well	Pozo
9	212	Villena	03	03140	PATOJO 2	10-07-06	13.0	Well	Pozo
10	212	Villena	03	03140	PATOJO 2	15-01-07	14.0	Well	Pozo
11	215	Villena	03	03140	BARRANCO	28-03-07	4.0	Well	Pozo
12	215	Villena	03	03140	BARRANCO	19-09-06	2.0	Well	Pozo
13	216	Villena	03	03140	ALHORINES	20-02-07	11.0	Well	Pozo
14	216	Villena	03	03140	ALHORINES	01-08-06	9.0	Well	Pozo
15	217	Crevillent	03	03059	STA. BERTA DEL	06-11-06	39.0	Well	Pozo
16	217	Crevillent	03	03059	STA. BERTA DEL	19-07-07	59.0	Well	Pozo
17	218	Crevillent	03	03059	(LA	19-07-07	68.0	Well	Pozo
18	218	Crevillent	03	03059	(LA	24-01-08	0.0	Well	Pozo
19	218	Crevillent	03	03059	(LA	06-11-06	106.0	Well	Pozo
20	225	Albatera	03	03005	(S.A.T. Nº 3569)	25-01-07	7.0	Well	Pozo
21	225	Albatera	03	03005	(S.A.T. Nº 3569)	23-08-07	8.0	Well	Pozo
22	228	Horadada	03	03902	(JOSE MTNEZ.	14-11-06	1.0	Well	Pozo
23	228	Horadada	03	03902	(JOSE MTNEZ.	26-06-07	1.0	Well	Pozo
24	229	Horadada	03	03902	MARTINEZ	23-10-06	1.0	Well	Pozo
25	229	Horadada	03	03902	MARTINEZ	17-05-07	1.0	Well	Pozo
26	208	Elda	03	03066	MARTINEZ	06-11-06	51.0	Well	Pozo
27	208	Elda	03	03066	MARTINEZ	12-09-07	7.0	Well	Pozo
28	231	Alzira	46	46017	LA COMA	11-09-06	67.0	Well	Pozo
29	231	Alzira	46	46017	LA COMA	22-03-07	72.0	Well	Pozo
30	207	Elda	03	03066	GARRIGOS	12-09-07	91.0	Well	Pozo
31	207	Elda	03	03066	GARRIGOS	06-11-06	86.0	Well	Pozo
32	236	Algemesi	46	46029	POZO BRUGADA	28-05-07	134.0	Well	Pozo
33	236	Algemesi	46	46029	POZO BRUGADA	16-10-06	126.0	Well	Pozo
34	237	Valldigna	46	46238	P. ULLAL TERME	29-08-07	99.0	Well	Pozo

7.2. Climate data

In the [climate_year_month] table the monthly climate information is saved. In the distributed version of the model these data refer to some european countries (Denmark, Germany, Norway, Italy, Spain and United Kingdom). In case the user wants to use climate data from outside these countries they can create their own climate table with specific data from their area on the basis of the structure of the “climate_year_month” table (Table 18). The fields of this table are:

- Climate_id: numeric identification code of each weather station,
- Weather station: name of the weather station,
- Year: the year of the sampling date,
- Month: the month of the sampling date in number format from 1 to 12,
- Tmean: average temperature of each month in °C,

- Rain: cumulative rainfall of each month in mm,
- Days_of_rainfall: number of days of each month with rainfall over 0.1 mm, and
- ETo: cumulative reference evapotranspiration of each month in mm.

Table 18. Table “climate_year_month” where the climate data of each month arranged by weather station is saved

	A	B	C	D	E	F	G	H	I	J	K	L
1	climate_id	IdProvincia	IdEstacion	Weather_station	Year	Month	Tmean	Tmax	Tmin	Rain	Days of rainfall	ETo
2	number	number	number	text	number	number	number	number	number	number	number	number
3	46101	46	101	Moncada IVIA	1992	1	13.14	2.02	7.58	0.0	0	36.0
4	46101	46	101	Moncada IVIA	1992	2	15.85	2.21	9.03	58.4	4	54.2
5	46101	46	101	Moncada IVIA	1992	3	18.76	7.71	13.23	5.9	3	109.4
6	46101	46	101	Moncada IVIA	1992	4	20.88	8.48	14.68	0.0	0	134.1
7	46101	46	101	Moncada IVIA	1992	5	24.77	13.06	18.92	78.8	1	155.8
8	46101	46	101	Moncada IVIA	1992	6	24.35	13.38	18.87	68.7	7	154.9
9	46101	46	101	Moncada IVIA	1992	7	28.97	16.34	22.65	0.0	0	210.4
10	46101	46	101	Moncada IVIA	1992	8	30.76	18.68	24.72	0.0	0	206.6
11	46101	46	101	Moncada IVIA	1992	9	26.10	16.13	21.12	73.7	3	124.7
12	46101	46	101	Moncada IVIA	1992	10	23.02	11.69	17.35	66.5	8	83.8
13	46101	46	101	Moncada IVIA	1992	11	22.13	7.20	14.67	0.0	0	71.8
14	46101	46	101	Moncada IVIA	1992	12	15.98	6.39	11.19	57.2	1	55.9
15	46101	46	101	Moncada IVIA	1993	1	15.70	2.28	9.20	6.6	1	51.4
16	46101	46	101	Moncada IVIA	1993	2	14.38	4.45	9.41	90.1	10	62.1
17	46101	46	101	Moncada IVIA	1993	3	16.81	4.37	10.59	27.0	3	98.1
18	46101	46	101	Moncada IVIA	1993	4	20.72	7.53	14.13	63.2	4	147.3
19	46101	46	101	Moncada IVIA	1993	5	23.40	12.09	17.75	24.6	9	172.4
20	46101	46	101	Moncada IVIA	1993	6	27.44	15.32	21.38	1.2	2	200.5
21	46101	46	101	Moncada IVIA	1993	7	28.01	18.12	23.07	10.2	1	222.1
22	46101	46	101	Moncada IVIA	1993	8	29.74	18.62	24.18	5.9	3	199.3
23	46101	46	101	Moncada IVIA	1993	9	27.06	14.08	20.57	29.0	7	175.6
24	46101	46	101	Moncada IVIA	1993	10	21.55	10.92	16.24	66.6	8	121.1
25	46101	46	101	Moncada IVIA	1993	11	17.26	7.09	12.18	58.1	7	64.9
26	46101	46	101	Moncada IVIA	1993	12	17.52	4.51	11.01	3.0	1	58.7
27	46101	46	101	Moncada IVIA	1994	1	16.31	3.79	10.05	0.6	1	67.9
28	46101	46	101	Moncada IVIA	1994	2	18.28	4.90	11.59	1.3	2	83.7

In the *windows* version of the model a dialog box has been created (Fig. 24) where the user can modify the table where the climate data are saved (e.g., “Climate_user”). This box can be accessed from the drop-down menu [Database → Climate], and once there, pressing the [Edit] button the user can modify all the data that are shown in the table.

Once the data have been modified the [OK] button must be pressed, so that the changes take effect and the system updates the table to “Climate_” plus the name the user has chosen in the “nitirsoil.mdb” database. At the same time, the original table is preserved by renaming it to: “Climate_” plus the name the user has chosen plus the date and time of the modification with the following format “_dd_mm_aaaa_hh:mm:ss”. This way the original table is kept, so as in case the user wants to retrieve it, this can be done simply by opening the “nitirsoil.mdb” database and changing the name “Climate_user_03_12_2012_14:26:34” to the name “Climate_user”. This way the old table would be ready to be used by the model.

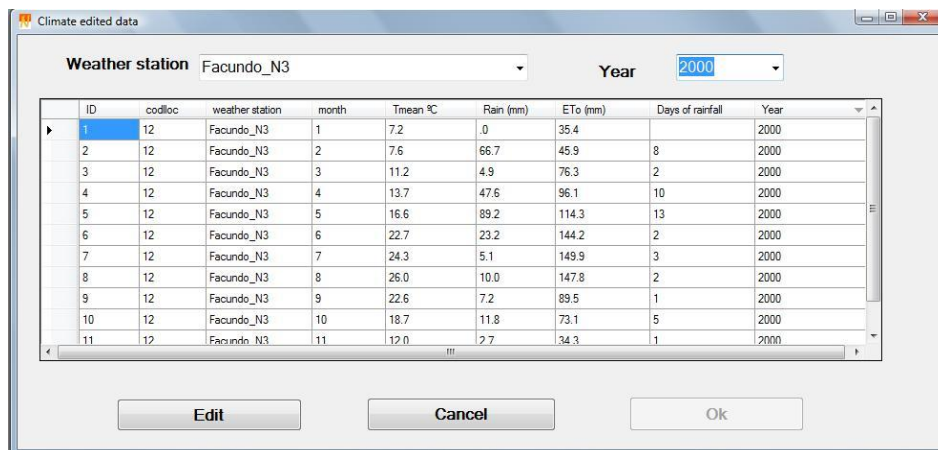


Figure 24. Dialog box for the climate data edition

7.3. Soil data

The model saves the soil data in two separate tables which are linked to one another by means of a code. In the first table (soil_gen_def) the soil location and hydrologic group are saved, and in the second one (soil_parameters) the data with the physicochemical characteristics of the soil are saved arranged by depths.

In the distributed version of the model, data from 83 soil points distributed throughout the main irrigation areas of several European countries have been included. In those areas from this territory where there is no available information, the system will offer six soil types with differentiated hydrological characteristics, from a sandy to a clay soil. Besides, there are also tools available so as to create user-own soil data tables.

The “Soil_gen_def” table saves the basic data from the soil location (Country and region) as well as the hydrologic group (Table 19). The fields of this table are:

- soil_id: soil type code,
- Name: profile or field name where the soil is located,
- Country_name: country name where the soil is located,
- Region: Region name where the soil is located,
- Code_region: Unique code for each region of the European countries,
- GH: hidrologic group, which is classified into A, B, C, and D depending on the soil and drainage characteristics (Table 1).

In the *batch* version of the model only the “soil_id”, for soil identification, and GH, for the hydrologic group, are considered.

Table 19. Table “soil_gen_def” where the location and hydrologic group data are saved

	A	B	C	D	E	F	G	H
1	soil_id	NAME	id_provincia	Province	Municipality	CODE_PROV_TM	CODE_TM	GH
2	number	text	texto	text	text	text	text	text
3	1	Alcachofa_facundo	46	Valencia	moncada	46126	126	B
4	2	Alcachofa_lloris	46	Valencia	moncada	46126	126	B
5	3	alcachofa_massanasa	46	Valencia	Massanasa	46165	165	B
6	4	VILLENA_Puntal3	3	Alicante	Villena	3140	140	C
7	5	VILLENA_Puntal2	3	Alicante	Villena	3140	140	B
8	6	VILLENA_Puntal1	3	Alicante	Villena	3140	140	B
9	7	Col_china_esp_1	46	Valencia	moncada	46171	171	B
10	8	Col_china_esp_2	46	Valencia	moncada	46171	171	B
11	9	Col_china_esp_3	46	Valencia	moncada	46171	171	B
12	10	Col_china_barat	46	Valencia	moncada	46171	171	B
13	11	coliflor_matadero	46	Valencia	burjassot	46078	78	C
14	12	coliflor_paterna	46	Valencia	Paterna	46980	980	B
15	13	puerro_villena	3	Alicante	Villena	3140	140	C
16	14	zanahoria_villena_ant_1	3	Alicante	Villena	3140	140	C
17	15	zanahoria_villena_ant_3	3	Alicante	Villena	3140	140	C
18	16	romanesco_carpesa	46	Valencia	carpesa	46016	16	C
19	17	romanesco_poble_nou	46	Valencia	poble nou	46025	25	B
20	18	lechuga_poble_nou	46	Valencia	poble nou	46025	25	B
21	19	cebolla_vinalesa	46	Valencia	vinalesa	46114	114	C
22	20	cebolla_poble_nou	46	Valencia	poble nou	46025	25	C
23	21	patata_rafa_ros_92	46	Valencia	moncada	46171	171	C
24	22	patata_antonio_castello_94	46	Valencia	moncada	46171	171	C
25	23	sandia_tavernes_07	46	Valencia	tavernes blanques	46016	16	B
26	24	sandia_moncada_07	46	Valencia	moncada	46171	171	B
27	25	sandia_burjassot_07	46	Valencia	burjassot	46100	100	B
28	26	Col_china_carpesa	46	Valencia	carpesa	46016	16	B
29	27	Col_lom_carpesa	46	Valencia	carpesa	46016	16	B
30	28	Col_lom_moncada	46	Valencia	moncada	46016	16	B
31	29	Col_lom_tavernes_07	46	Valencia	tavernes blanques	46016	16	B
32								

The table “Soil_parameters” store the soil parameters differentiated by depths or layers (Table 20). The fields of this table are:

- Soil_id: soil code that links this table with the other one “soil_gen_def” with numbers from 1 to n,
- Top_cm: depth of the top boundary of the soil layer in cm,
- Bottom_cm: depth of the bottom boundary of the soil layer in cm,
- BD_gr_cm3: bulk density of the soil layer in g/cm³,
- H_saturation: water content at saturation of the soil layer expressed in 1/u,
- Sand: percent of sand-sized particles ($\emptyset > 0.050$ mm) of the soil layer according to the USDA textural classification,
- Clay: percent of clay-sized particles ($\emptyset < 0.002$ mm) of the soil layer according to the USDA textural classification,
- pH: pH value of the soil layer,
- OM: percent of organic matter of the soil layer,
- C_N: carbon-to-nitrogen ratio of the soil layer, in case this information is not available the model takes 10 by default,
- FC_cm_cm: water content of the soil layer at field capacity in cm³/cm³,
- WP_cm_cm: water content of the soil layer at permanent wilting point in cm³/cm³,
- CF: percent of coarse fragments ($\emptyset > 2$ mm) in the soil layer.

Table 20. Table “Soil_parameters” where the physicochemical data of the soils arranged by depths are saved

1	B	D	E	F	H	I	J	K	L	M	N	O	P	Q	R	S
2	soil_id	Top cm	Bottom cm	BO gr cm3	H saturation	sand	silt	Clay	texture_USDA	ph	OM	C N	FC cm cm	WP cm cm	arbonates percent	EG
3	number	number	number	number	number	number	number	number	text	number	number	number	number	number	number	number
4	1	30	60	1.63	0.38	23.00	42.00	35.00	Clay Loam	7.90	1.03	10.00	0.33	0.23	20.0	0.00
5	1	60	90	1.72	0.35	39.00	33.00	28.00	Clay Loam	7.90	0.51	10.00	0.31	0.20	20.0	0.00
6	1	0	30	1.45	0.42	46.00	32.00	22.00	Loam	7.90	1.37	10.00	0.27	0.12	20.8	0.00
7	2	0	30	1.48	0.41	52.00	29.00	19.00	loam	8.00	1.88	10.00	0.24	0.10	20.8	0.00
8	2	30	60	1.64	0.38	26.00	42.00	32.00	Clay Loam	8.10	1.03	10.00	0.32	0.22	20.0	0.00
9	2	60	90	1.67	0.36	39.00	34.00	27.00	loam	8.10	0.51	10.00	0.30	0.19	20.0	0.00
10	3	0	30	1.41	0.43	52.00	30.00	18.00	Clay-loam	8.00	1.20	10.00	0.27	0.10	20.0	0.00
11	3	30	60	1.69	0.40	28.00	42.00	30.00	Clay-loam	7.90	1.03	10.00	0.31	0.21	20.0	0.00
12	3	60	90	1.67	0.36	38.00	34.00	28.00	Clay-loam	7.90	0.68	10.00	0.30	0.19	20.0	0.00
13	4	0	30	1.36	0.50	19.70	41.50	38.80	Silty Clay	8.40	2.50	10.00	0.38	0.24	20.0	0.00
14	4	30	60	1.41	0.51	15.00	40.40	44.60	Silty Clay	8.50	1.70	10.00	0.41	0.27	20.0	0.00
15	5	0	15	1.36	0.45	30.36	43.63	26.01	Loam	8.24	1.66	10.00	0.32	0.17	20.0	0.00
16	5	15	30	1.36	0.45	32.37	41.37	26.25	Loam	8.30	1.48	10.00	0.31	0.17	20.0	0.00
17	5	30	60	1.41	0.43	35.51	35.69	28.80	Clay Loam	8.40	0.93	10.00	0.31	0.18	20.0	0.00
18	6	0	30	1.41	0.47	20.97	44.68	34.33	Clay Loam	8.30	1.49	10.00	0.36	0.21	20.0	0.00
19	6	30	60	1.48	0.48	11.46	52.00	36.53	Silty Clay	8.35	1.12	10.00	0.37	0.22	20.0	0.00
20	6	60	90	1.64	0.43	38.58	30.50	30.92	Clay Loam	8.27	0.58	10.00	0.31	0.19	20.0	0.00
21	7	0	30	1.54	0.43	51.98	28.16	19.86	Loam	8.05	1.65	10.00	0.35	0.12	20.0	0.00
22	7	30	60	1.70	0.44	30.57	39.11	30.32	Clay Loam	8.27	1.01	10.00	0.35	0.21	20.0	0.00
23	7	60	90	1.78	0.42	40.99	30.96	28.06	Clay Loam	8.37	0.64	10.00	0.32	0.19	20.0	0.00
24	8	0	30	1.47	0.42	63.66	21.45	14.89	Sandy Loam	8.20	1.55	10.00	0.35	0.08	20.0	0.00
25	8	30	60	1.57	0.45	28.79	40.50	30.71	Clay Loam	8.30	1.04	10.00	0.38	0.21	20.0	0.00
26	8	60	90	1.83	0.44	29.47	40.21	30.33	Clay Loam	8.50	0.78	10.00	0.31	0.21	20.0	0.00
27	9	0	30	1.50	0.43	45.37	28.63	26.01	Loam	8.05	1.39	10.00	0.29	0.16	20.0	0.00
28	9	30	60	1.68	0.48	18.91	41.78	39.31	Silty Clay	8.27	1.08	10.00	0.38	0.24	20.0	0.00
29	9	60	90	1.75	0.50	13.02	41.31	45.67	Silty Clay	8.37	0.93	10.00	0.41	0.27	20.0	0.00
30	10	0	30	1.53	0.42	62.19	24.91	12.90	Sandy Loam	8.13	1.54	10.00	0.19	0.09	20.0	0.00
31	10	30	60	1.62	0.44	33.82	37.02	29.16	Clay Loam	7.70	1.07	10.00	0.32	0.18	20.0	0.00

In the same way that a dialog box has been designed to edit the climate table, another dialog box has been designed to help the user modify the table where the soil data is saved (e.g., “Soil_user”, figure 25). This box is accessed from the drop-down menu [Database access → Soil], and pressing the [Edit] button the user can edit all the data that are shown in the table.

Once modified, the [OK] button must be pressed for the changes to take effect, and the system to update the table to “Soil_” plus the name the user has chosen in the “nitirsoil.mdb” database. At the same time the original table is preserved by renaming it to “Soil_” plus the name the user has chosen, and plus the date and time of modification with the format “_dd_mm_aaaa_hh:mm:ss“ (e.g., Soil_user_03_12_2021_14:26:34). This way the original table is always kept, so in case the user wants to retrieve it, this can be done by simply opening the “nitirsoil.mdb” database and changing the name “Soil_user_03_12_2021_14:26:34” by the name “Soil_user”. This way the old table would be ready to be used by the model.

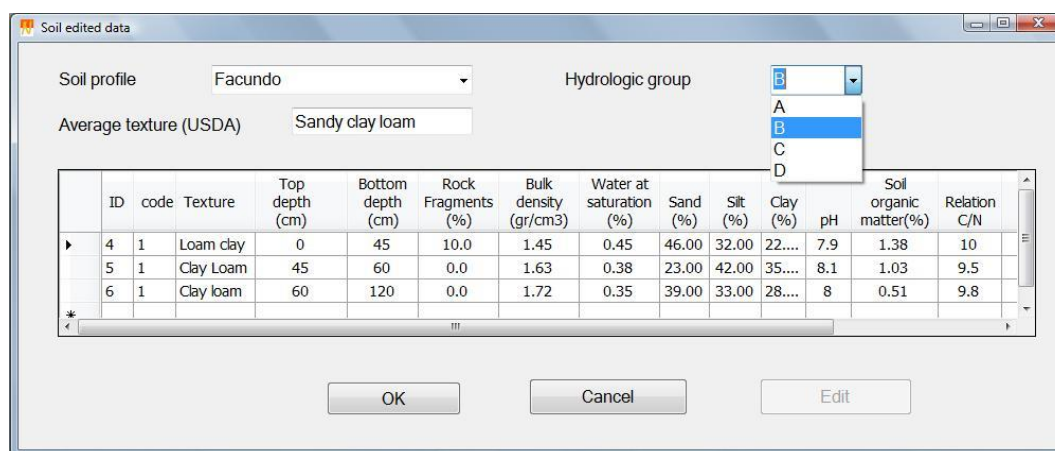


Figure 25. Dialog box for the edition of the soil data

7.4. Mineral fertilizers

The characteristics of the mineral nitrogen fertilizers are saved in the “Fertilizer” table (Table 21). The model in its *windows* version unfolds this table from the mineral fertilizer management menu so the user can easily include the fertilizers in their schedule.

Table 21. Table “Fertilizer” where the nitrogen mineral fertilizers characteristics are saved

1	A	B	C	D	E	F	G	H	I	J
2	id	code_id	Fertilizante	Fertilizer	forma	form	N_TOT	N_NH4	N_NO3	
3	autonumero	numero	Texto	Texto	Texto	Texto	numero	numero	numero	
3	1	1	Sulfato amónico	Ammonium sulfate	solido	solid	20.6	20.6	0	
4	2	2	Fosfato diamónico	Diammonium Phosphate	solido	solid	18	18	0	
5	3	3	Fosfato monoamónico	Monoammonium	solido	solid	12	12	0	
6	4	4	Cloruro amónico	Ammonium Chloride	solido	solid	24	24	0	
7	5	5	Nitrato potásico	Potassium Nitrate	solido	solid	13.5	0	13.5	
8	6	6	Nitrato cálcico	Calcium Nitrate	solido	solid	15.5	0	15.5	
9	7	7	Nitrato Amónico	Ammonium Nitrate	solido	solid	33.5	16.8	16.7	
10	8	8	Nitrato amónico cálcico	Calcium ammonium	solido	solid	27	13.5	13.5	
11	9	9	Nitromagnesio	Magnesium nitrate	solido	solid	22	11	11	
12	10	10	Nitro-Sulfato Amonico	Ammonium nitrate-	solido	solid	26	19.5	6.5	
13	11	11	15-15-15	15-15-15	solido	solid	15	8	7	
14	12	12	20-10-5	20-10-5	solido	solid	20	14.25	5.75	
15	13	13	Urea	Urea	solido	solid	46	46	0	
16	14	14	ENTEC-20	ENTEC-20	solido	solid	20	11	9	
17	15	15	Amoniaco	Liquid ammonia	liquido	liquid	82	82	0	
18	16	16	Solucion nitrato amónico	Ammonium Nitrate +	liquido	liquid	32	24	8	
19	17	17	Solucion Nitrogenada 20	Nitrogen solution 20	liquido	liquid	20	10	10	
20	18	18	Solucion Nitrogenada 32	Nitrogen solution 32	liquido	liquid	32	24	8	
21	19	19	Solucion Nitrato calcio 8	Nitrogen solution	liquido	liquid	8	0	8	
22	20	20	Solucion Nitrato calcio y	Nitrogen solution	liquido	liquid	7	0	7	
23	21	21	Acido nítrico	Nitric Acid	liquido	liquid	13	0	13	
24	22	22	15-15-15	15-15-15	solido	solid	15	15	0	
25	23	23	10-20-10	10-20-10	solido	solid	10	10	0	
26	24	24	12-15-15	12-15-15	solido	solid	12	12	0	
27	25	25	12-24-12	12-24-12	solido	solid	12	12	0	
28	26	26	8-24-16	8-24-16	solido	solid	8	8	0	
29	27	27	8-24-8	8-24-8	solido	solid	8	8	0	
30	28	28	8-18-8	8-18-8	solido	solid	8	8	0	
31	29	29	8-15-15	8-15-15	solido	solid	8	8	0	
32	30	30	7-18-10	7-18-10	solido	solid	7	7	0	
33	31	31	7-14-14	7-14-14	solido	solid	7	7	0	
34	32	32	7-12-7	7-12-7	solido	solid	7	7	0	
35	33	33	5-10-15	5-10-15	solido	solid	5	5	0	
36	34	34	Nitrofoska 20-5-10	Nitrofoska 20-5-10	solido	solid	20	10.5	9.5	
37	35	35	12-12-17	12-12-17	solido	solid	12	7	5	
38	36	36	NITROFOSKA-18	NITROFOSKA-18	solido	solid	18	9.1	8.9	
39	37	37	Potasa Rubv	Potasa Rubv	solido	solid	2	0	2	

Specifically, in the [Fertilizer] table, the data about the physical state and nitric and ammonium composition of the nitrogen fertilizers are saved. The fields that make up this table are the following:

- code_id: identification code of each fertilizer,
- Fertilizer: name of the fertilizer,
- forma: physical state (solid or liquid) in which the fertilizer is found,
- N_TOT: total N percent of the fertilizer,
- N_NH4: ammonium N percent of the fertilizer, and
- N_NO3: nitric N percent of the fertilizer.

The addition of N_NO3 plus N_NH4 must match N_TOT.

This table can be edited by using a dialog box that has been designed for this purpose (Fig. 26). This box is accessed by means of the drop-down menu [Database access → Mineral fertilizer].

In order to visualize and select the fertilizer to modify, the list of fertilizers “Fertilizer” must be unfolded. Once the fertilizer has been selected, in the group “Edit Options” the action the user wants to perform is selected:

- Show: the fertilizer data are shown but they cannot be edited,

- Edit: the fertilizer data are shown and they can be edited and modified,
- Remove: the selected fertilizer can be deleted,
- Add new: add a new fertilizer to the table of fertilizers,

For the action chosen by the user to take effect, the [OK] button must subsequently be pressed.

Figure 26. Dialog box for the edition of the mineral fertilizers

7.5. Organic fertilizers

The characteristics of the organic fertilizers are saved in the “Manure” table (Table 22). This table is the one that the model unfolds from the organic fertilizer management menu.

Specifically, in the [Manure] table the characteristics of the organic fertilizers are saved according to the following fields:

- Code: organic fertilizer identification number code,
- Type: name of the organic fertilizer: poultry droppings, beef manure, etc.,
- Form: physical state of the fertilizer (solid, liquid, slurry),
- Total N: total-N-to-dry-matter ratio in percentage,
- N-NO3: nitric-N-to-dry-matter ratio in percentage,
- N-NH4: ammonium-N-to-dry-matter ratio in percentage,
- OM: percent of oxidizable organic matter of the fertilizer on a dry matter basis,
- CN: carbon-to-nitrogen ratio of the fertilizer, and
- Moisture: fertilizer water content in percentage.

Table 22. “Manure” table where the data about the characteristics of the nitrogen organic fertilizers are saved

	A	B	C	D	E	F	G	H	I	J
1	code	type	tipo	Form	Total N	N-NO3	N-NH4	OM	CN	Moisture
2	number	text	text	text	number	number	number	number	number	number
3	1	Beef	Vacuno	Solid	3	0.03	1.05	75	11.00	45
4	2	Dairy	vacuno_lechero	Solid	4.4	0.02	1.06	86	13.00	40
5	3	Horse	Caballo	Solid	2	0	0	80	12.00	40
6	4	Municipal sludge	Lodos_depuradora	Slurry	4.1	0.002	1.28	58.8	8.28	60
7	5	Poultry	Gallinaza	Solid	2.5	0.03	1.05	75	11.00	45
8	6	Sheep	Oveja	Solid	4.5	0.01	1.44	84.2	12.00	30
9	7	Swine	Cerdo	Solid	7.5	0.01	3.2	80	10.00	30
10	8	Beef	Vacuno_lodo	Slurry	10	0.26	3.8	80	15.00	85
11	9	Dairy	vacuno_lechero_lodo	Slurry	18	0.133	7	86	13.00	85
12	10	Swine	Cerdo_lodo	Slurry	6.66	0.13	4.26	80	10.00	85
13	11	Beef	Vacuno_liquido	Liquid	7.5	0.25	5	3.75	15.00	96
14	12	Dairy	Vacuno_lechero_liquido	Liquid	7.25	0.25	4.75	3.25	13.00	96
15	13	Poultry	Gallinaza_liquido	Liquid	8.5	0.25	7.25	3	11.00	96
16	14	Swine	Cerdo_liquido	Liquid	7	0.25	5.75	3.5	10.00	96
17										

This table can be edited by means of a dialog box that has been designed for this purpose (Fig. 27). This dialog box can be accessed through the drop-down menu [Database access → Manures].

In order to visualize and select the fertilizer to modify, the list of organic fertilizers “Manure type” must be unfolded. Once the fertilizer has been selected, in the group “Edit Options” the action the user wants to perform must be selected:

- Show: the fertilizer data are shown but they cannot be edited,
- Edit: the fertilizer data are shown and they can be edited and modified,
- Remove: the selected fertilizer can be deleted,
- Add new: add a new fertilizer to the table of fertilizers,

For the action chosen by the user to take effect, the [OK] button must subsequently be pressed.

Figure 27. Dialog box for the edition of the organic fertilizers

8. Tables that are updated with each simulation

In each run of the model in its windows version, the tables "Batch_crops_growth" where the data that characterize the growth of the crop is added (Table 23), the "Batch_crops_irrigat" table (Table 24) where the data featuring the irrigation management, the "Batch_crops_N" table where the nitrogen fertilization management data is added (Table 8), and the "Input_table_main" table where the general data is stored (Table 1) are updated, according to the data entered by the user in each simulation.

8.1.- General input data

In the [Input_table_main] table, the general input data in the model is stored, such as the relational codes with other tables (irrigation, soil, crop, climate, etc.), the name of the simulation, the planting dates, simulation initial day, production yield, initial crop conditions, etc. according to the structure described in section 4.2.1.1. (general simulation data) of the NITIRSOIL model in its "Batch" version.

8.1. Crop growth

In the [Batch_crops_growth] table the values of the basal crop coefficients (Kcb), the rooting depth, and the canopy cover percentage for each of the natural months during which the crop has developed, are saved. The fields of the table are the following:

- Crop_id: identification code of the simulated crop,
- Month: month in number format,
- Kcb: basal crop coefficients for each month,
- rd_cm: rooting depth for each month in cm, and
- shaded_area: canopy cover area for each month expressed in 1/u.

Table 23. Table "Batch_crops_growth" where the monthly crop growth data of each simulation are saved

	A	B	C	D	E	F	G
1	Id	Crop_id	Crop/s	month	Kcb	rd_cm	shaded_area
2	1	200 Melon_N1		1	0.00	0.0	0.00
3	2	200 Melon_N1		2	0.00	0.0	0.00
4	3	200 Melon_N1		3	0.00	0.0	0.00
5	4	200 Melon_N1		4	0.00	0.0	0.00
6	5	200 Melon_N1		5	0.23	18.6	0.17
7	6	200 Melon_N1		6	0.59	47.1	0.44
8	7	200 Melon_N1		7	1.00	80.0	0.75
9	8	200 Melon_N1		8	0.81	58.3	0.55
10	9	200 Melon_N1		9	0.00	0.0	0.00
11	10	200 Melon_N1		10	0.00	0.0	0.00
12	11	200 Melon_N1		11	0.00	0.0	0.00
13	12	200 Melon_N1		12	0.00	0.0	0.00
14	13	258 artichoke_N3		1	0.98	60.0	0.75
15	14	258 artichoke_N3		2	0.98	60.0	0.75
16	15	258 artichoke_N3		3	0.98	60.0	0.75
17	16	258 artichoke_N3		4	0.69	42.4	0.53
18	17	258 artichoke_N3		5	0.26	8.2	0.10
19	18	258 artichoke_N3		6	0.00	0.0	0.00
20	19	258 artichoke_N3		7	0.00	0.0	0.00
21	20	258 artichoke_N3		8	0.31	13.3	0.17
22	21	258 artichoke_N3		9	0.43	26.3	0.33
23	22	258 artichoke_N3		10	0.47	28.6	0.36
24	23	258 artichoke_N3		11	0.74	45.2	0.57
25	24	258 artichoke_N3		12	0.98	60.0	0.75
26	25	259 artichoke_N1		1	0.98	60.0	0.75
27	26	259 artichoke_N1		2	0.98	60.0	0.75

8.2. Irrigation management

In the [Batch_crops_irrigat] table the data on irrigation rate and frequency, and percent of soil moistened area are saved once the day of plantation and growing length have been decided (table 24). The fields of this table are the following:

- Irrigat_id: identification code of the irrigation schedule,
- Irrigation: name of the simulation,
- I..._mm: irrigation rate for each month in mm: Ijan_mm, Ifeb_mm, Imar_mm, Iapr_mm, Imay_mm, Ijun_mm, Ijul_mm, Iaug_mm, Isep_mm, Ioct_mm, Inov_mm, Idec_mm, and
- If..._day: number of days a month with irrigation: Ifjan_day, Iffeb_day, Ifmar_day, Ifapr_day, Ifmay_day, Ifjun_day, Ifjul_day, Iaug_day, Ifsep_day, Ifoct_day, Ifnov_day, Ifdec_day.

Table 24: Table “Batch_crops_irrigat” where the data about the irrigation management of each simulation is saved

1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
	Irrigat_id	Irrigation	Ijan_mm	Ifeb_mm	Imar_mm	Iapr_mm	Imay_mm	Ijun_mm	Ijul_mm	Iaug_mm	Isep_mm	Ioct_mm	Inov_mm	Idec_mm	Ifjan_day	Iffeb_day	Ifmar_
2	200	Melon_N1	0	0	0	0	137	64	58	52	0	0	0	0	0	0	0
3	258	artichoke_N3	0	21	22	17	0	0	0	35	0	0	0	0	0	0	1
4	259	artichoke_N1	0	21	22	17	0	0	0	35	0	0	0	0	0	0	1
5	260	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
6	261	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
7	262	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
8	263	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
9	264	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
10	265	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
11	266	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
12	267	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
13	268	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
14	269	artichoke_facundo_N3	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
15	270	facundo_organico	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
16	315	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
17	316	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
18	317	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
19	318	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
20	319	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
21	320	alcachofa_F3_manure	150	35	30	87	0	0	0	101	70	80	138	56	3	1	1
22	321	CEBOLLA_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
23	322	ONION_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
24	323	ONION_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
25	324	ONION_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
26	325	ONION_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
27	326	ONION_POBLE_NOU	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
28	327	onion_poble_nou_org	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
29	328	onion_poble_nou_org	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
30	329	onion_poble_nou_org	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
31	330	onion_poble_nou_org	49	19	47	81	0	0	0	0	0	0	73	30	2	1	1
32	331	prueba	48	0	115	98	0	0	0	46	0	0	38	10	1	0	0
33	332	prueba	17	36	73	88	27	0	0	5	0	0	0	5	1	1	1
34	333	MINERALIZACION	0	51	0	26	38	101	143	167	42	45	0	19	0	2	2
35	334	MINERALIZACION	0	51	0	26	38	101	143	167	42	45	0	19	0	2	2
36	335	prueba	0	21	22	22	0	0	0	29	0	0	0	0	0	0	1
37	336	prueba	0	21	22	25	0	0	0	26	0	0	0	0	0	0	1
38	337	prueba	0	21	22	27	0	0	0	23	0	0	0	0	0	0	1
39	338	prueba	0	21	22	37	0	0	0	11	0	0	0	0	0	0	1

From the [Edit irrigation management] button the user can access to the content of this table “Batch_crops_irrigat” where the irrigation management plans are stored from other simulations. In order to load a specific irrigation management the user can select the plan and then pres the [load irrigation plan] button.

9. Format of the user-created input data tables

9.1. Climate

The table in the “nitirsoil_batch.mdb” in MS Access© where the local climate data are stored must start by “Climate_” and then whatever character string chosen by the user, for example “Climate_user”. In this table all the climate data from all the weather stations and years the user wants to use in the simulations, will be saved. The setting up

of this table can be made in the MS Excel© workbook “nitirsoil_batch.xls” and then imported into the database in MS Access© (see Annex I).

9.1.1. Fields of the climate table

- ID: autonumber value that increases in one unit each time a new record is entered into the table. It has been generated previously and matches the one in the table “Input_table_main”,
- Climate_id: number code of the weather station,
- Weather_station: name of the weather station. This field can be used to include whichever name that identifies the plot, area, etc.,
- Month: month number from 1 to 12,
- Tmean: monthly mean temperature (°C),
- Rain: monthly rainfall (mm),
- ETo: monthly reference evapotranspiration (mm),
- Days of rainfall: number of days a month with rainfall, and
- Year: the year of data registered.

9.2. Soil

The table in the “nitirsoil.mdb” database in MS Access© where the soil data are stored must start with “Soil_”, and then whichever character string chosen by the user, for example: “Soil_user”. In this table all the soil data, arranged by layers or horizons from all locations and/or plots the user wants to use in the simulations, will be stored.

9.2.1. Fields of the soil table

- ID: autonumber code of the soil table. It is a field that increases in one unit each time a new record is entered into the table,
- Code: numeric identification code of each soil profile that it is included in the soil table,
- Perfil: name of the soil profile,
- Top_cm: higher boundary of each soil layer (cm),
- Botton_cm: lower boundary of each soil layer (cm),
- BD_gr_cm3: soil bulk density of each soil layer (g/cm^3),
- H_saturation: soil water content at saturation (1/ud),
- Sand: percent of sand-sized particles according to the USDA classification,
- Silt: percent of silt-sized particles according to the USDA classification,
- Clay: percent of clay-sized particles according to the USDA classification,
- Texture_USDA: USDA soil textural classification,
- pH: soil pH value,

- OM: percent of soil organic matter (%),
- C_N: carbon-to-nitrogen ratio, by default it is taken as 10,
- FC_cm_cm: soil water content at field capacity (cm^3/cm^3),
- WP_cm_cm: soil water content at permanent wilting point (cm^3/cm^3),
- CF: percent of soil coarse ($\varnothing > 2 \text{ mm}$) fragments (%),
- GH: general hydrologic group of the soil profile (Table 1). This value is repeated as many times as layers are in the soil profile, and
- Text_USDA: soil average texture of the soil profile according to the USDA classification. This value is repeated as many times as layers are in the soil profile.

The same procedure that has been followed to create the table with the climate data can be followed to create the soil table.

10. Installation of the NITIRSOIL model

In order to installate the NITIRSOIL model the computer must have:

- An MS Windows© operating system: XP, Vista, 7, 10 etc.
- The MS Access© program, it is recommended the 2003 version or higher.

Next, how to proceed to carry out the installation of the NITIRSOIL is indicated.

Run the “setup.exe” file, a setup wizard will open, which will guide the user to correctly install the model (Fig. 28).

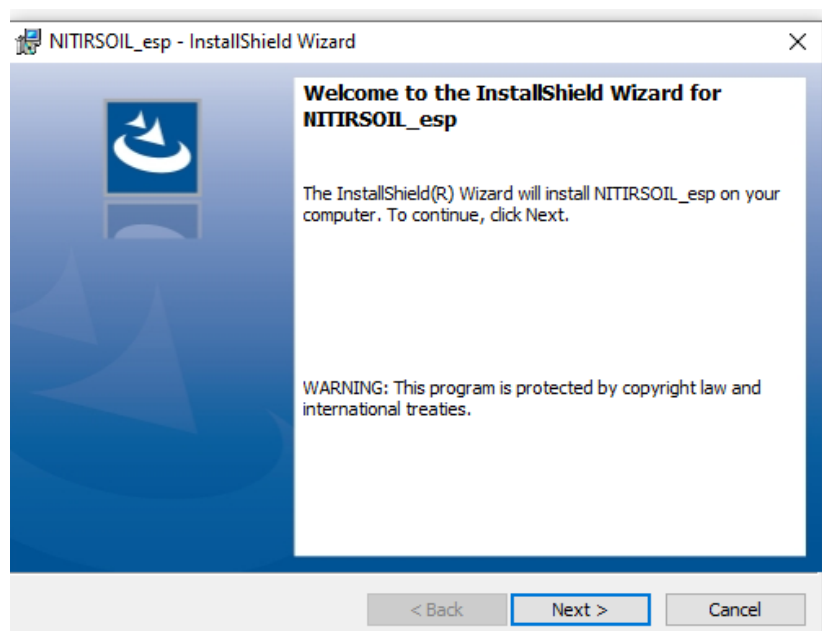


Figura 28. First dialog box for NITIRSOIL model installation

Press the [Next >] button, and the second dialog box of the installation wizard will pop-up (Fig. 29). In this dialog box you can select the folder where to install the model. The

database (nitirsoil.mdb or nitirsoil_batch.mdb) as well as the Excel spreadsheets “Clima_suelo_usuario.xls” or “tables_run.xls” will be installed inside the [database] folder that will be generated from the installation directory [NITIRSOIL]. To do this, press the [Change] button, which will open another dialog box in which you can search and select, or create, the folder where the application will be installed (Fig. 30).

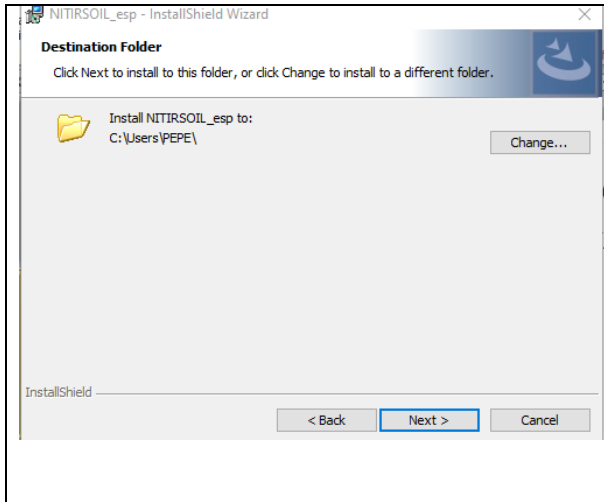


Figura 29. Segundo cuadro de diálogo para la instalación del modelo NITIRSOIL.

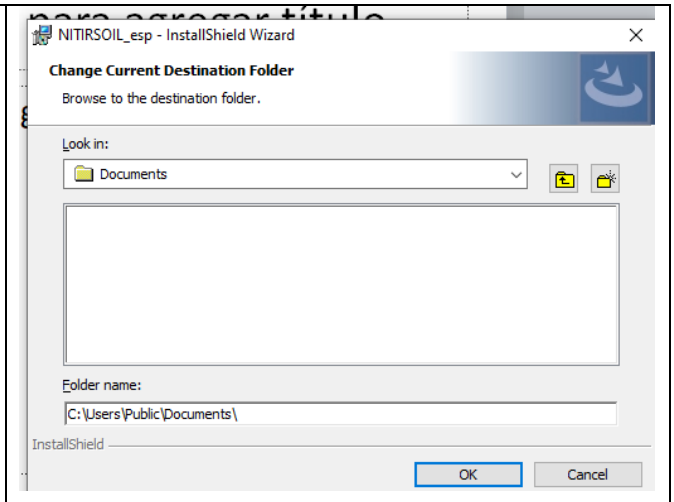


Figura 30. Cuadro para la selección del directorio donde instalar el modelo.

Una vez seleccionado el directorio donde se instalará el modelo, aparecerá un cuadro de dialogo con el que se iniciará la instalación apretando el botón [Install] (Fig. 32). En la instalación se crearán los accesos directos al modelo que se ubicaran en el menú de programas.

Once the directory, where the model will be installed, has been selected, a dialog box will appear for starting the installation by pressing the [Install] button (Fig. 31). In the installation, a direct access to the model will be created, and located in the programs menu.

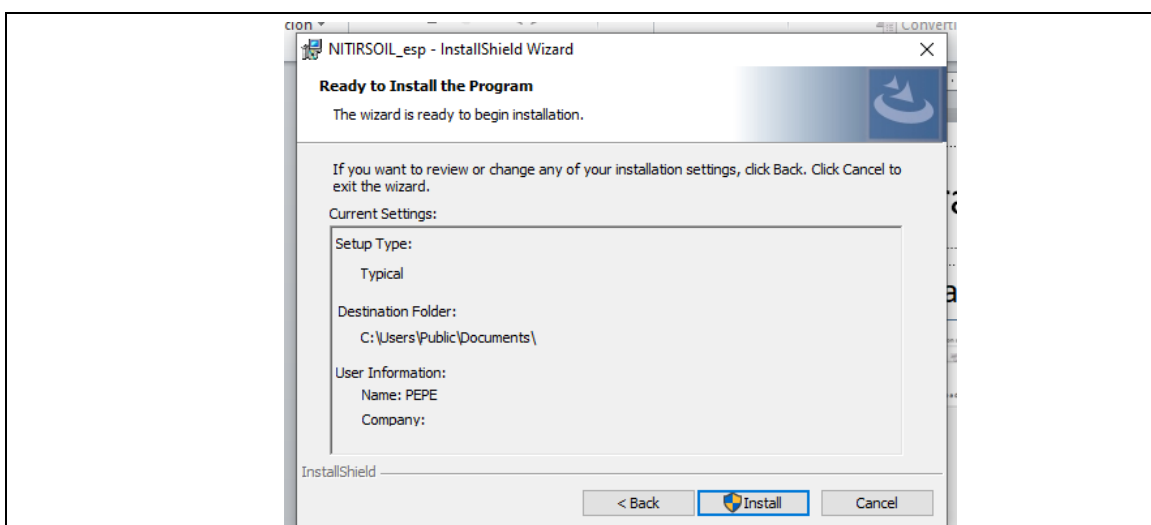


Figura 31. Dialog box for starting the model installation

In order to confirm the correct installation of the model, a final dialog box will appear confirming it (Fig. 33). This box gives the option to run the model once installed. The installation will be finished by pressing the [Finish] button.

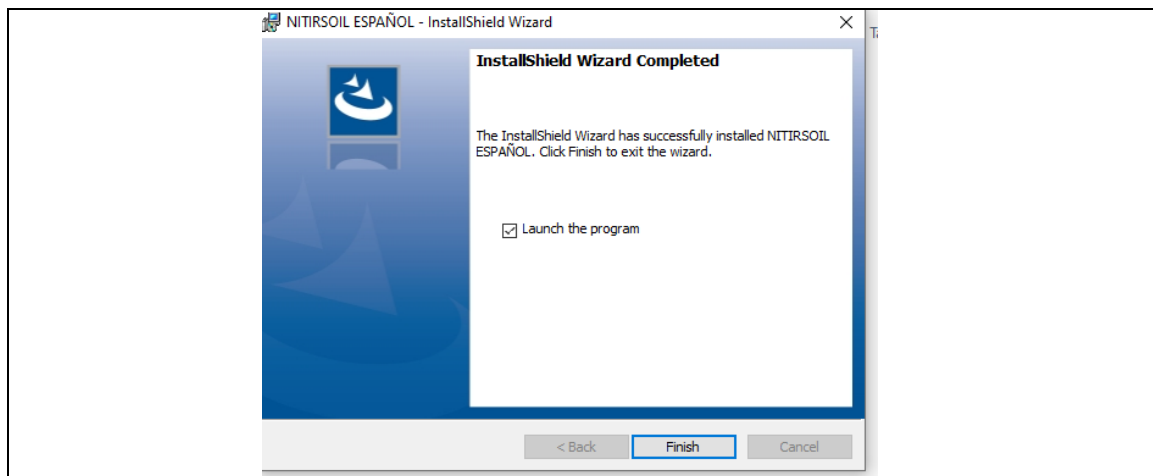


Figura 32. Cuadro final de confirmación de la instalación del modelo NITIRSOIL



If the NITIRSOIL model is already installed on the computer, and you need to install it again, you must first uninstall it before to start the new installation.

II) Algorithms of the NITIRSOIL model

1. Module for the water balance assessment

The module that simulates the water movement in the soil-plant-atmosphere system has been taken from the SALTIRSOIL_M model, which was made for the monthly simulation of soil salinity in well-drained irrigated areas (Visconti and de Paz, 2012; Visconti et al., 2014).

In this module a transient-state approach is followed to the simulation of the water movement in the soil, which is based on a tipping-bucket algorithm from one soil layer to the underlying one. According to this algorithm, each of the soil layers in which its depth is conceptually split, firstly, can hold water only until its field capacity, releasing the surplus to the underlying layer and, secondly, can release water to the plant roots from its field capacity until its permanent wilting point.

Regarding the ability of the plant roots to extract water, the crop evapotranspiration calculation is based on the Penman-Monteith equation, and the dual crop coefficient (Allen et al., 2006). As a consequence, in case of water shortage for meeting the crop evapotranspiration, the model calculates an actual evapotranspiration. From these values, a water stress coefficient as a function of the available plant water, which is adapted from the one proposed by Martin Santa Olalla and de Juan (1993).

2. Module for the crop development assessment

The crop development is simulated in a very simple way following a sigmoidal curve, which can be approached with a sigmoid function or a polynomial. By means of this sigmoidal curve the cumulated fraction of total dry matter (FTDM) as a function of the crop season elapsed time fraction (x) is calculated:

$$x = (t - t_0)/(t_h - t_0) \quad (1),$$

where t , t_0 , and t_h , are, respectively, the elapsed time, the plantation and the harvest date.

In case of citrus the following sigmoid function is used:

$$FTDM = 1.02/[1 + e^{(4.85 - 8.79 x)}] \quad (2),$$

whereas, in case of vegetables the following fourth-degree polynomial is used:

$$FTDM = 0.143 x + 1.876 x^2 - 0.467 x^3 - 0.552 x^4 \quad (3).$$

According to this sigmoidal development model, there is a slow initial growth, which gradually accelerates and then, it slows more and more as ripening closes in as it is shown in Fig. 33.

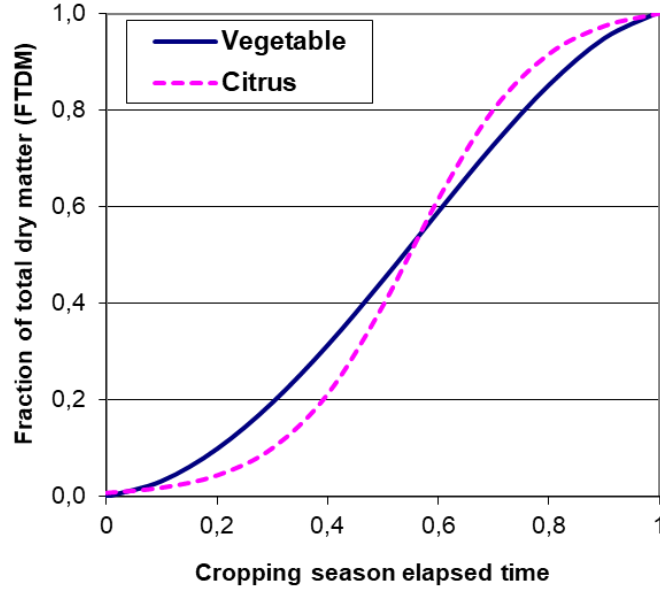


Figure 33. Estimation of the cumulated fraction of total dry matter as a function of the crop development elapsed time for a vegetable crop and a citrus where x is the crop development elapsed time fraction according to Eq. 1

Next, the total produced dry matter (TDM), and its distribution between harvest and residue is estimated using classical parameters such as fresh harvest yield (FY) in t/ha, as well as harvest index, which is calculated as:

$$HI = DMY/TDM \quad (4),$$

and the dry-matter-to-fresh-yield calculated as:

$$DM = DMY/FY \quad (5).$$

Besides, the model makes the total produced dry matter (TDM) to depend on the existence or absence of some water stress throughout the crop development months by means of the water stress coefficient ($K_{stress,i}$), which is calculated for each month i as:

$$K_{stress,i} = ETr_i/ETc_i \quad (6),$$

i.e., as the ratio of actual evapotranspiration (ETr_i) to crop evapotranspiration (ETc_i), which ranges between 0 and 1, and whose application for the total produced and harvested dry matter only will occur when the user activates it on the general input data menu.

As a consequence, the total crop dry matter produced each month i (TDM_i) is:

$$TDM_i = FTDM_i \times PY \times DM/HI \times K_{stress,i} \quad (7),$$

and furthermore, the dry matter yield of the harvested (DMY) and non-harvested (DMNY) crop parts is calculated as:

$$DMY_i = FTDM_i \times PY \times DM \times K_{stress,i} \quad (8),$$

$$DMNY_i = TDM_i - DMY_i \quad (9),$$

The values of HI and DM have been determined from field trials of the main horticultural crops on the Valencian Community (de Paz et al., 2022b), and they have been completed with other values found in the literature for the case of those crops for which information from local studies was not available.

3. Module for the nitrogen balance assessment

3.1. Assessment of factors before the estimation of the nitrogen balance

3.1.1. Stress factor due to soil temperature

In the NITIRSOIL model a stress factor due to soil temperature is calculated, and it is used to regulate several processes which occur in the soil such as mineralization, both of the organic matter and the contributions from the organic fertilizers, the denitrification, volatilization and nitrification.

The calculation of this temperature stress factor is based on the equation from the Arrhenius theory which was calibrated with data from Gilmour (1984) and Marion and Black (1987). This Arrhenius equation is applied to T values below 35 °C:

$$K_{\max} = e^{(A/(T + 273)) + B} \quad (10),$$

where A stands for the ratio of activation energy at constant pressure and e^B stands for a frequency factor.

This Arrhenius equation it taken as a basis for the establishment of the one in the model, according to which the factor is doubled every 10 °C until 35 °C, and then, it is divided by two every 10 °C. Therefore, the equation takes the following form:

$$T_{\text{FAC}} = e^{(A/(T_{\text{mod}} + 273)) + B} \quad (11),$$

where A = 6532.7 and B = 21.24 and T_{mod} is:

$$\begin{aligned} \text{if } T \leq 35 \text{ °C} & \quad \rightarrow \quad T_{\text{mod}} = T \\ \text{if } T > 35 \text{ °C} & \quad \rightarrow \quad T_{\text{mod}} = 70 - T \end{aligned} \quad (12),$$

where T is the soil temperature in Celsius degrees, which is considered equal to the atmospheric temperature.

The T_{FAC} stress factor ranges between 0 and 1. It presents a value almost null at temperatures near 0 °C, and increases as temperature climbs up to 35 °C, value from which it decreases matching the decline the microbial soil life activity experiences.

In Fig. 34 it is shown the comparison among different equations for the estimation of T_{FAC} . In the NITIRSOIL model it is followed the one in the NLEAP model.

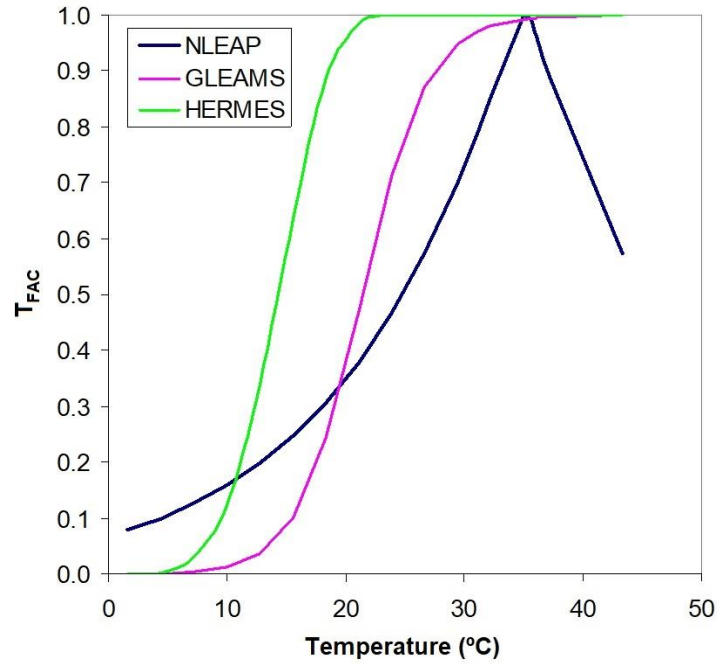


Figure 34. Values of the T_{FAC} stress factor for the NLEAP, GLEAMS and HERMES models as a function of temperature

3.1.2. Stress factors due to soil water content

In the NITIRSOIL model it is used a soil water content stress factor so as to regulate the aerobic processes ($W_{FAC,a}$) such as nitrification and the soil organic matter and the organic fertilizers mineralization, which is based on the one implemented in the NLEAP model according to the following expressions:

$$\begin{aligned}
 \text{if } WFP \leq 20 \% & \quad \rightarrow \quad W_{FAC,a} = 0.0075 WFP \\
 \text{if } 20 < WFP < 59 \% & \quad \rightarrow \quad W_{FAC,a} = - 0.253 + 0.0203 WFP \\
 \text{if } WFP \geq 59 \% & \quad \rightarrow \quad W_{FAC,a} = 41.1 e^{-0.0625 WFP} \quad (13),
 \end{aligned}$$

where WFP is the percent of water-filled pore space (%).

For the anaerobic processes such as denitrification another stress factor ($W_{FAC,an}$) is used, which considers that these processes are only produced with WFP values over 59%, according to the following expressions:

$$\begin{aligned}
 \text{if } WFP < 59 \% & \quad \rightarrow \quad W_{FAC,an} = 0 \\
 \text{if } WFP \geq 59 \% & \quad \rightarrow \quad W_{FAC,an} = 0.000304 e^{0.0815 WFP} \quad (14).
 \end{aligned}$$

The WFP value of 59% corresponds to approximately the soil water content at field capacity in which the micropores and mesopores are filled with water, but not the macropores.

The value of the W_{FAC} coefficients according to the equations 6 and 7 has been graphed in Fig. 35 by comparing them to the ones implemented in the GLEAMS model (Knisel 1993).

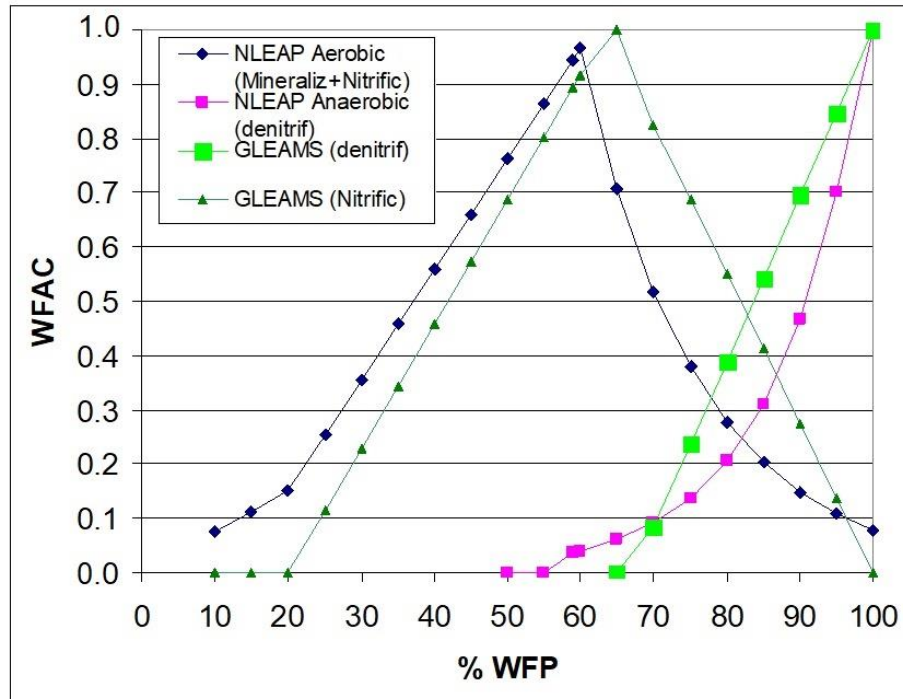


Figure 35. Variation of the soil water content stress factor (W_{FAC}) as a function of the percent of water-filled pore space (WFP) for the NLEAP and NITIRSOIL and GLEAMS models, which affect the processes of mineralization and denitrification (Linn and Doran 1984)

For the assessment of the percent of water-filled pore space (WFP) the following expression is used:

$$WFP = 100 \text{ SWC/POR} \quad (15),$$

where SWC is the soil water content and POR its porosity. The porosity is calculated from the bulk density (BD) expressed in units of g/cm^3 by means of the following equation:

$$POR = 1 - BD/2.65 \quad (16),$$

or either, it is taken equal to the soil water content at saturation (SAT) if it is known:

$$POR = SAT \quad (17).$$

The soil water content of each month is calculated from the water balance that is performed by the corresponding module within the model itself.



The W_{FAC} factor is very sensitive to the point of field capacity (FC) and saturation (SAT). The closer the FC and SAT are, the larger the W_{FAC} values will be, since the WFP values are generally higher. This W_{FAC} factor is calculated each month before the drainage to the underlying layers occurs.

3.2. Assessment of the input terms of the nitrogen balance

3.2.1. Mineralization of the soil organic matter

The process of mineralization of the soil organic matter is considered limited to the soil surface layer, which is taken from 0 to 30 cm depth in the model. Besides, it is

considered that 5% of the fast-mineralized N goes to the slow mineralization pool (immobilization).

The equations that determine the soil organic matter mineralization are two, one for the organic matter of slow mineralization and another for the one of fast mineralization.

For the organic matter of slow mineralization the equation is the following:

$$N_{\min_slow} = \frac{\frac{SOM_{sup}}{1.72 \times 100} \times K_{omr_slow} \times BD_{sup} \times \frac{100 - CF_{sup}}{100} \times LT \times T_{FAC} \times W_{FAC,a} \times ITIME \times f}{(C/N)_{slow}} \times \frac{100 - N_{no_pool}}{100} \quad (18),$$

whereas for the organic matter of fast mineralization the equation is this other:

$$N_{\min_fast} = \frac{\frac{SOM_1}{1.72 \times 100} \times K_{omr_fast} \times BD_1 \times \frac{100 - CF_1}{100} \times LT \times T_{FAC} \times W_{FAC} \times ITIME \times f}{(C/N)_{fast}} \times \frac{N_{no_pool}}{100} \quad (19).$$

where

SOM_{sup} is the percent of soil organic matter in the surface soil layer (%),

BD_{sup} is the bulk density in the soil surface layer (g/cm^3),

CF_{sup} is the percent of coarse fragments ($\emptyset > 2$ mm) in the soil surface layer (%),

LT_{sup} is the thickness of the soil surface layer (cm). In NITIRSOIL is taken as 30 cm,

T_{FAC} is the temperature stress factor (0 - 1),

$W_{FAC,a}$ is the water content stress factor (0 - 1),

$(C/N)_{slow}$ is the carbon-to-nitrogen ratio in the soil organic matter of slow mineralization. It is taken equal to the soil C/N ratio, which is 10 by default,

$(C/N)_{fast}$ is the carbon-to-nitrogen ratio in the soil organic matter of fast mineralization. It is 17 by default,

K_{omr_slow} is the mineralization coefficient for the soil organic matter of slow mineralization. It is 0.00037 ud/day by default,

K_{omr_fast} is the mineralization coefficient for the soil organic matter of fast mineralization. It is 0.0059 ud/day by default,

ITIME is the number of days of the month (ud),

f is the factor to change units from g_N/cm^2 to kg_N/ha , which is 100000, and

N_{no_pool} is the percent of organic matter of fast mineralization. By default we can say it is 10% for horticultural soils since many crop residues are of fast mineralization, and 5% for woody crop including citrus, since the produced residues are of slower mineralization rate.

It can be given a percent of organic N of fast mineralization that will be between 5-10% of the soil organic matter.

3.2.2. Mineralization of manures, sludges and other organic materials

The net mineralized nitrogen from the organic materials added to the soil as crop residues, manure, etc., in a certain time, e.g., one month, are calculated according to this equation:

$$NRESR = CRESR \times FVAL \quad (20),$$

where

NRESR is the net mineralized nitrogen from the material added each month in kg_N/ha/day,

FVAL is the nitrogen mineralization-immobilization factor, and

CRESR is the mineralized carbon from the material contributed each month in kg_C/ha/day.

The nitrogen mineralization-immobilization factor (FVAL) is calculated according to:

$$NRESR = CRESR \left(\frac{1}{C/N} - 0.042 \right) \quad (21),$$

where C/N is updated each month. In Fig. 36 it is shown how FVAL varies with the C/N ratio. This factor continually decreases with the C/N ratio, but remarkably at high values and less and less as C/N increases.

High C/N values are observed in poorly evolved organic materials, from which there is hardly any mineralization (FVAL ≈ 0) or, even, there is immobilization of the mineral soil N (FVAL < 0). Low C/N values are observed in fairly evolved organic materials, from which there is net nitrogen mineralization (FVAL > 0). At a C/N of 23.8, it goes from nitrogen mineralization to immobilization.

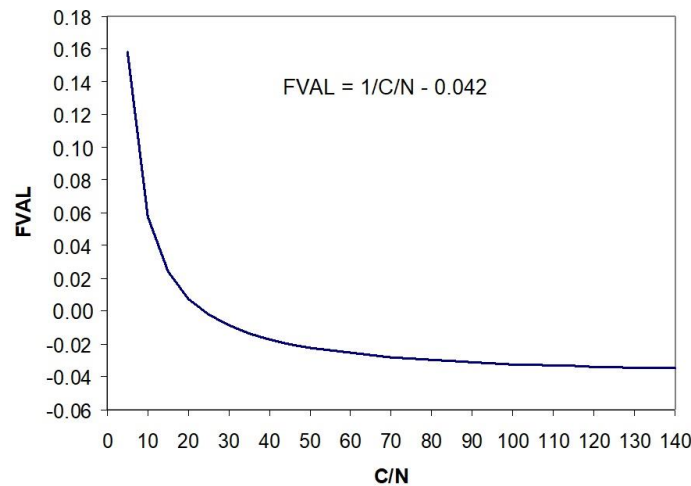


Figure 36. Variation of the FVAL value as a function of the evolution of the C/N ratio of the organic matter

The net mineralized carbon (CRESR) from the organic materials is calculated as follows:

$$CRESR = K_{\text{cres}} \times CRES \times T_{\text{FAC}} \times W_{\text{FAC,a}} \times \text{ITIME} \quad (22),$$

where the T_{FAC} , $W_{\text{FAC,a}}$ and ITIME factors have been previously defined,

K_{cres} is the mineralization coefficient of the applied organic material, which

- if it is animal manure is worth 0.03 1/day,
- if it is crop residue is worth 0.06 1/day, and
- if it is another type or residue is worth 0.003 1/day.

CRES is the C content of the organic material expressed in kg_C/ha which is calculated as:

$$\text{CRES} = \text{Pc} \times \text{RES} \quad (23),$$

where RES is the rate of organic material expressed as weight of dry matter per hectare (kg/ha), and

Pc is the percent of carbon in the residues on a dry matter basis, which is calculated as:

$$\text{Pc} = \text{OM} (\%) / 172 \quad (24),$$

where it has been supposed that the carbon percentage of the oxidizable organic matter (OM) from the residues is 58%. In case of having an organic material, from which its percentage of oxidizable organic matter is not known, the model will take by default the following values for Pc:

- if it is manure then 0.37,
- if it is crop residue then 0.4, and
- if it is other residues then 0.30.

Besides, the CRES value, or amount of total carbon contributed with the organic material, is calculated as:

$$\text{RES} = 10 \times \text{DOSE} \times (100 - \text{RESWC}) \quad (25),$$

where DOSE is the residues rate in t/ha , RESWC is the percent of water content of the residues, and 10 is a factor of units conversion.

Therefore, the calculation of CRES is finally:

$$\text{CRES} = 10 \times \text{Pc} \times \text{DOSE} \times (100 - \text{RESWC}) \quad (26).$$

The CRES value is updated each month (i) regarding the previous (i - 1) by subtracting the amount mineralized during the month from the carbon that there was at the beginning:

$$\text{CRES}_i = \text{CRES}_{i-1} - \text{CRESR} \quad (27),$$

on the condition that $\text{CRES}_i \geq 0$, which means that carbon cannot present negative values.

Once the ith month CRES has been calculated (CRES_i) the nitrogen value in the residues that month is estimated (NRES_i) by previously updating the C/N value for the ith month ($[\text{C}/\text{N}]_i$) by means of:

$$[\text{C}/\text{N}]_i = \text{CRES}_i / \text{NRES}_i \quad (28).$$

Therefore, the NRES value will be updated each month i as follows:

$$\text{NRES}_i = \text{NRES}_{i-1} - \text{NRESR} \quad (29),$$

on the condition that $\text{NRESR} \geq -(\text{N-NH}_4^+ + \text{N-NO}_3^-)_{\text{superf}}$, which means that it cannot be immobilized (negative mineralization) more nitrogen than the mineral nitrogen that exists in the soil ($\text{N-NH}_4^+ + \text{N-NO}_3^-$). If this is not the case, NRESR is calculated through the following equation:

$$\text{NRESR} = -(\text{N-NH}_4^+ + \text{N-NO}_3^-)_{\text{superf}} \quad (30),$$

and NRES_i is calculated by means of:

$$\text{NRES}_i = \text{NRES}_{i-1} + (\text{N-NH}_4^+ + \text{N-NO}_3^-)_{\text{superf}} \quad (31).$$

3.2.3. Nitrification of soil ammonium

The nitrification is the transformation of N-NH_4^+ into N-NO_3^- by the action of aerobic chemolithoautotrophs microorganisms. The nitrification usually lasts few days, unless there are some moisture and temperature conditions that delay it, or if a fertilizer with a nitrification inhibitor is applied (ENTECH type).

There are several proposals to model nitrification, from zero-order and Monod to first-order kinetics. Because the mineralization process is much slower than nitrification, it is considered that the transformation of NH_4^+ to NO_3^- is almost immediate although it has been observed in the field that it can last several days or even weeks (Hansen et al. 1995). In the case of monthly models such as NITIRSOIL, the nitrification process is produced in a time scale one order of magnitude shorter than the model step. Accordingly, nitrification can be simulated by means of simple kinetics. Moreover, other models, such as RZWQM initially used more complex first-order kinetics, but it was noted that it did not affect the C and N dynamics, and as a result, zero-order kinetics has been implemented.

The NITIRSOIL model follows the algorithms of the NLEAP model, which considers zero-order kinetics that is modified by the water content and stress factors previously presented:

$$N_n = K_n \times K_{\text{inhi}} \times T_{\text{FAC}} \times W_{\text{FAC,a}} \times \text{ITIME} \quad (32),$$

where ITIME is the month length in days, which would be 30 days for a normal month with the nitrification coefficient K_n expressed in $\text{kg}_\text{N}/\text{ha}/\text{day}$. The K_n value in NITIRSOIL is by default 33.6 kg N/ha/day . With this nitrification coefficient, if a 30-day month is considered, and with no restrictions regarding soil N-NH_4^+ , and neither to water content and temperature, the maximum nitrification would be $1008 \text{ kg N/ha/month}$. This amount is high for one month, which exposes the nitrification speed. Finally, K_{inhi} is the coefficient of nitrification inhibition, which varies between 0 and 1, being 0 for the total inhibition, and 1 for the absence of inhibition.

The condition must always be met that no more ammonium is nitrified than exists in the soil, i.e., $N_n \leq \text{N-NH}_{4i}$, where N-NH_{4i} is the N-NH_4^+ content in the superficial soil layer. For the calculation of the amount of ammonium which is liable to nitrification the following balance is calculated:

$$\text{N-NH}_{4,i} = \text{N-NH}_{4,i-1} + \text{N-NH}_{4\text{fert},i} + \text{N-NH}_{4\text{min_som},i} + \text{N-NH}_{4\text{min_est},i} - \text{N-NH}_{4\text{vol},i} \quad (33),$$

where

$\text{N-NH}_{4,i}$ is the ammonium nitrogen content in the superficial soil layer (0-30 cm) at the end of the i th month,

$\text{N-NH}_{4,i-1}$ is the ammonium nitrogen content in the superficial soil layer at the end of the previous month,

$\text{N-NH}_{4\text{fert},i}$ is the ammonium nitrogen contributed by the mineral fertilization in the i th month,

$\text{N-NH}_{4\text{min_som},i}$ is the ammonium nitrogen content contributed by the mineralization of the organic matter in the i th month,

$\text{N-NH}_{4\text{min_est},i}$ is the ammonium nitrogen contributed by the mineralization of manure in the i th month, and

$N-NH_{4vol,i}$ is the volatilized ammonium nitrogen in the i th month.

3.3. Assessment of the output terms of the nitrogen balance

3.3.1. Crop nitrogen uptake

The crop N uptake is calculated in NITIRSOIL as the minimum between the crop N demand, and the available-for-crop-extraction soil N:

$$N_{\text{uptake}} = \min(N_{\text{demand}}, N_{\text{available}}) \quad (34),$$

where the crop N demand each month i is calculated with the following equation:

$$N_{\text{demand},i} (\text{kg}_N/\text{ha}) = 10 \times \text{TDM}_i \times \%N_i \quad (35),$$

where TDM_i is the crop total dry matter production in t/ha accumulated until the i th month, calculated according to equation 7, $\%N_i$ is the percent of crop nitrogen in the i th month, and 10 is a factor for units conversion.

The calculation of the percent of crop N for each month is based on a potential-type equation called crop N dilution curve, which is shown below:

$$\%N_i = a \times \text{TDM}_i^{-b} \quad (36),$$

where “a” and “b” are coefficients that depend on the crop type. In Fig. 37 it is graphed the evolution of the N content (%) as a function of the cumulated fraction of total dry matter for several crops during their development.

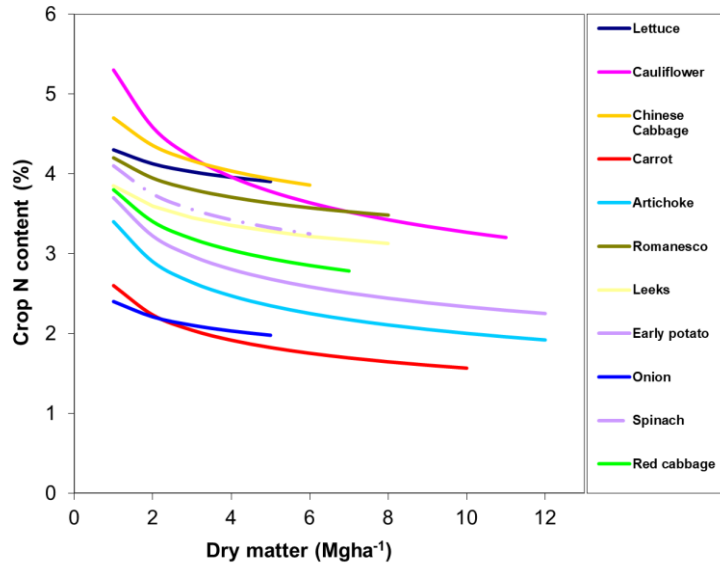


Figure 37. Variation of %N content of several vegetables crops as a function of the total dry matter.

The calculation of the cumulated crop N demand until the i th month is:

$$\sum N_{\text{demand},i} (\text{kg}_N/\text{ha}) = 10 \times \text{TDM}_i \times \%N_i \quad (37).$$

Since this is the cumulated demand until the i th month, in order to calculate the N demand the i th month, the cumulated demand until the previous month ($i - 1$) must be subtracted from the cumulated demand until the present month (i). Therefore, to calculate the N_{demand} in a certain month i ($N_{\text{demand},i}$) the following formula is applied:

$$N_{\text{demand},i} (\text{kg}_N/\text{ha}) = \sum N_{\text{demand},i} - \sum N_{\text{demand},i-1} \quad (38).$$

Once the N the crop potentially demand is calculated, this demand is distributed to the soil layers the root explores (1, 2, 3, ...), and it is compared with the available soil N in those layers, which is the addition of N-NH_4^+ plus N-NO_3^- :

$$N_{\text{available},1} = \text{N-NH}_{4,1} + \text{N-NO}_{3,1} \quad (39),$$

$$N_{\text{available},2} = \text{N-NH}_{4,2} + \text{N-NO}_{3,2} \quad (40),$$

$$N_{\text{available},3} = \text{N-NH}_{4,3} + \text{N-NO}_{3,3} \quad (41),$$

...

Finally, the actual crop N uptake the *i*th month is calculated as the minimum of the values between the soil available N, and the crop N demand the month of interest:

$$N_{\text{uptake},i} = \min(N_{\text{available},i}, N_{\text{demand},i}) \quad (42).$$

In case the crop potential demand can be met by the soil available N, the actual crop N uptake matches the potential crop N uptake. In the opposite case, in which the crop potential demand cannot be met by the soil nitrogen, the model simulates an actual uptake that matches the soil availability. This calculation is performed month by month, and soil layer by layer.

Besides, the model adds all the crop N uptake during the crop months, and divide them by the nitrogen inputs to calculate the nitrogen uptake efficiency (NUE):

$$\text{NUE}(\%) = 100 \times \frac{N_{\text{uptake}}}{N_{\text{min_initial_soil}} + N_{\text{fert_min}} + N_{\text{irrig}} + N_{\text{fert_org}}} \quad (43).$$

The NUE values between 50-90% are considered efficient as long as the nitrogen excess ($N_{\text{uptake}} - N_{\text{min_initial_soil}} - N_{\text{fert_min}} - N_{\text{irrig}} - N_{\text{fert_org}}$) is below 90 kg_N/ha, according to the European panel of N experts (Oenema et al. 2011).

3.3.2. Denitrification

The denitrification calculation in NITIRSOIL is performed similarly to how is done in the NLEAP model, in which a first-order kinetics is adopted to simulate this process. Besides, the denitrification is decomposed in three terms, one for the days with irrigation, another for the days with rainfall, and another one for the days with neither irrigation nor rainfall that occur during the month. This way, the total denitrified N-NO_3^- at the end of the month (N_{dn}) is calculated as the addition of three values:

$$N_{\text{dn}} = N_{\text{dn_irrig}} + N_{\text{dn_rain}} + N_{\text{dn_dry}} \quad (44).$$

where $N_{\text{dn_irrig}}$ is the denitrified N-NO_3^- the irrigation days, $N_{\text{dn_rain}}$ is the denitrified N-NO_3^- the rainfall days, and $N_{\text{dn_dry}}$ in the denitrified N-NO_3^- the days with neither rainfall nor irrigation.

For the rainfall days it is considered that $W_{\text{FAC,an}} = 1$ in the area moistened by the irrigation, and $W_{\text{FAC,an}} \neq 1$ in the non-moistened one, and the following denitrification calculation is reached:

$$N_{\text{dn_irrig}} = K_{\text{dn}} \times \text{N-NO}_{3\text{sup}} \times T_{\text{FAC}} \times \text{Irrig_days} \times [\text{wetted_soil} + W_{\text{FAC,an}} \times (1 - \text{wetted_soil})] \quad (45),$$

where

K_{dn} is the denitrification coefficient (table 25), which can vary as a function of several factors: i) the percent of soil organic matter, ii) the soil drainage, iii) the type of tillage, iv) the existence of manure contributions, v) climate, and vi) the possibility of waterlogging. The year average K_{dn} is estimated using the following table (Meisinger and Randall 1991) with double entry (percent of soil organic matter and hydrologic group). This “parameter_desni” table can be accessed in the model database.

Table 25. Daily denitrification coefficients (K_{dn}) used in the NITIRSOIL model

Soil organic matter (%)	Soil type according to its drainage capacity				
	Very good	Good	Moderate	Somewhat restricted	Poor
	Hydrologic group				
	AA	A	B	C	D
< 2	0.02	0.03	0.04	0.06	0.10
2-5	0.03	0.04	0.06	0.1	0.15
> 5	0.04	0.06	0.1	0.15	0.25

In case of performing some manure application, the model increases the denitrification coefficients in 10%. Besides, if the irrigation management is by drip, the model increases the denitrification coefficient in 20% since the soil water content is kept uniform in values close to the field capacity.

$N\text{-NO}_{3sup}$ is the nitrogen in nitrate form in the surface soil layer (0-30 cm). This is taken as the existent $N\text{-NO}_3^-$ in the soil at the beginning of the month (and which can be considered as the residual one from the previous month), plus the $N\text{-NO}_3^-$ added with the irrigation and fertilization, and once that lost by volatilization during the ongoing month has been subtracted,

Irrig_days is the number of irrigation days a month,

wetted_soil is the soil fraction that is moistened with the irrigation (0 - 1), and

T_{FAC} and $W_{FAC,an}$ are the temperature and water content stress coefficients in anaerobic processes that have been previously defined.

According to Eq. 45, for irrigation days it is considered a different denitrification in the irrigation-moistened (wetted_soil) and in the non-moistened area ($W_{FAC} \times (1 - \text{wetted_soil})$). This is the most adequate way to simulate the denitrification in plots with drip irrigation in which only a little soil percent in moistened with each water application.

For rainfall days it is considered $W_{FAC,an} = 1$ as for irrigation ones, and denitrification is calculated as:

$$N_{dn_rain} = K_{dn} \times N\text{-NO}_{3sup} \times T_{FAC} \times \text{Rain_days} \quad (46),$$

where Rain_days is the number of rainfall days a month. It is considered as a rainfall day that with a cumulated rainfall over 0.4 mm. Besides, the rainfall days it is considered that the whole plot is moistened.

Finally, for the days with neither irrigation nor rainfall the denitrification is calculated as:

$$N_{dn_dry} = K_{dn} \times N\text{-NO}_{3sup} \times T_{FAC} \times W_{FAC,an} \times (\text{ITIME} - \text{Rain_days} - \text{Irrig_days}) \quad (47).$$

For the case in which there are more irrigation and rainfall days than days in the month ($\text{Rain_days} + \text{Irrig_days} > \text{ITIME}$), then according to Eq. 47 it would result $N_{\text{dn_dry}} < 0$, and when the model detects this it makes $N_{\text{dn_dry}} = 0$.

According to the presented calculations, denitrification is considered maximum during wet days, either because of rainfall or irrigation. Anyway, it can never occur that denitrification is over the total N-NO_3^- content in the soil surface layer (0-30 cm). That is to say, the condition that $N_{\text{dn}} \leq \text{N-NO}_{3\text{sup}}$ must hold.

3.3.3. Emission of N_2O to the atmosphere

The N_2O emissions are produced in both the nitrification and denitrification processes. The NITIRSOIL model uses an equation to estimate the N_2O emissions that are produced in the nitrification, and another to estimate the N_2O emissions that are produced in the denitrification.

It distinguishes between rainfall, irrigation and dry days, and the calculations are reassessed as a function of the moistened area. This way drip, furrow and flood irrigation can be simulated.

The N_2O emission produced in the nitrification is calculated as follows:

$$N_{\text{N}_2\text{O}_n} = K_{\text{n}_2\text{o_nitrif}} \times N_n \times f_t \times f_h \quad (48),$$

where

$K_{\text{n}_2\text{o_nitrif}}$ is the N_2O emission coefficient in the nitrification which is equal to 0.002,

N_n is the nitrified N-NH_4^+ according to what has been previously calculated,

f_t is temperature factor calculated as:

$$f_t = 0.9 \times T / (T + e^{(9.93 - 0.312 T)}) + 0.1 \quad (49),$$

and f_h is a soil moisture factor which depends on the soil water content (SWC) so that:

$$\text{if } \text{SWC} < \text{SWC}_{25} \quad \rightarrow \quad f_h = \max(0, (\text{SWC} - \text{PWP}) / (\text{SWC}_{25} - \text{PWP}))$$

$$\text{if } \text{SWC}_{25} \leq \text{SWC} \leq \text{FC} \quad \rightarrow \quad f_h = 1$$

$$\text{if } \text{SWC} > \text{FC} \quad \rightarrow \quad f_h = 1 - (\text{SWC} - \text{FC}) / (\text{POR} - \text{FC}) \quad (50),$$

where

SWC_{25} is the soil water content corresponding to 25% of usable water according to:

$$\text{SWC}_{25} = \text{PWP} + 0.25 \times (\text{FC} - \text{PWP}) \quad (51),$$

PWP is the soil water content corresponding to the permanent wilting point, and

FC is the soil water content corresponding to the field capacity.

Besides, the N_2O emission produced in the denitrification is calculated using the equations from the NOE model according to:

$$N_{\text{N}_2\text{O}_{\text{dn}}} = K_{\text{dnN}_2\text{O}} \times N_{\text{dn}} \times f_{\text{hN}_2\text{O}} \quad (52),$$

where

$K_{\text{dnN}_2\text{O}}$ is the N_2O emission coefficient in the denitrification equal to 0.2, and

f_{hN_2O} is the moisture factor in the N_2O emission by denitrification which is calculated as:

$$f_{hN_2O} = \max(0, 1 - 2.056 \times (\max(0, SWC/SAT - 0.5))) \quad (53).$$

3.3.4. Ammonium volatilization

The NITIRSOIL model calculates three ways of $N-NH_4^+$ volatilization as NH_3 :

1. From a mineral ammonium fertilization.
2. From an organic fertilization.
3. From the ammonium of the soil superficial layer itself the months in which there is not any fertilization that contributes $N-NH_4^+$.

According to this, the volatilization coefficient is calculated differently, since a short-term volatilization is considered, i.e., immediately after a fertilization, and another a long-term one, i.e., the months when there is no fertilization.

1. For the application of a mineral and/or organic fertilization:

$$N_{vol} = K_{vol} \times N-NH_4 \times T_{FAC} \times ITIME \quad (54),$$

considering that $N_{vol} \leq N-NH_{4superf}$

where

$N-NH_4$ is the ammonium N rate of the organic or mineral fertilization, and

K_{vol} is the volatilization coefficient which depends on the fertilization type (organic, mineral ammonium, etc.), on the way of application (superficial, incorporated, injected, etc.), on the soil water content, on the soil pH, on the soil cation exchange capacity, and on the percent of crop residues that exist on the surface. Specifically, NITIRSOIL uses the Table 26 for choosing the K_{vol} according to the values the aforementioned factors take.

Table 26. Value of the ammonium volatilization coefficient in Eq. 54 (K_{vol}) according to the fertilizer and its way of application, the probability of rainfall after the application and the soil pH

Fertilizer	Type of application	Type of month according to its humidity		
		Humid month	Sub-humid month	Dry month
pH > 7				
Urea	Superficial	10	15	25
	Incorporated	7	12	15
	Injected	1	2	2
Ammonium sulphate	Superficial	20	25	25
	Incorporated	1	2	0-32
	Injected	1	11	1
Ammonium nitrate	Superficial	0-20 (10)	2-25 (12)	5-30 (15)
	Incorporated	0-10 (3)	0-15	0-20
Ammonia	Injected	0-2	0-3	0-5
Organic	Superficial	18	20	23
	Incorporated	4	4	4
	Injected	0.1	0.1	0.1
pH < 7				
Urea	Superficial	0-5	5-30	5-40
	Bit-a-bit applied superficial	0-5	2-20	2-30

	Incorporated	0	0-2	0-2
	Superficial	0-5	2-15	2-20
N 32% solution (NUA)	Bit-a-bit applied superficial	0-5	2-10	2-15
	Incorporated	0	0-2	0-2

In order to classify the months according to their humidity and select the adequate K_{vol} in Table 27 the number of humid days is calculated, where a humid day is that with a cumulated rainfall or irrigation over 0.4 mm. Next, according to Table 25 the type of month according to its humidity is determined.

Table 27. Type of month according to its humidity as a function of the number of humid days of the month

Number of humid days a month	Type of month
< 10	Dry month
10-15	Sub-humid month
> 15	Humid month

The K_{vol} value found in Table 26 is next multiplied by a factor (f_{CEC}) that depends on the soil cation exchange capacity according to the following table 28:

Table 28. Cation exchange capacity depending factor (f_{CEC}) by which the ammonium volatilization coefficient found in Table 24 is multiplied

Cation exchange capacity (meq/100 g)	f_{CEC}
< 10	1.2
10-25	1.0
> 25	0.7

The model previously calculates the CEC using the following equation which was established for the agricultural soils to the southern area of Alicante (Visconti, 2009):

$$CIC \text{ (meq/100g)} = -1.2 + 2.3 \times SOM \text{ (\%)} + 0.28 \times \text{Clay (\%)} \quad (55).$$

For the case of a month in which no fertilization has been applied, the ammonium volatilization is calculated as follows:

$$N_{vol} = 0.05 \times N-NH_{4\text{superficial}} \quad (56),$$

where $N-NH_{4\text{superficial}}$ is the $N-NH_4^+$ content of the 0-30 cm depth soil layer

3.3.5. Nitrate leaching

The nitrate lost by leaching is calculated using the following equation:

$$N_L = N_{AL} \times (1 - e^{(-K_{lea} \times \text{drainage/POR})}) \quad (57),$$

where

N_L is the leached $N-NO_3^-$ from the soil layer (kg_N/ha),

N_{AL} is the available nitrogen for leaching from the soil layer,

drainage is the drainage from the soil layer (l/m^2),

POR is the soil porosity of the previously defined soil layer, and

K_{lea} is the leaching coefficient, which by default it taken equal to 0.5.

Equation 57 is applied soil layer by layer to simulate the nitrate movement through it. In the end, the model assesses the nitrate leached from the simulation depth the user has selected.

The nitrogen available for leaching (NAL) is calculated by N balance in each month and for each soil layer, according to the equation:

$$N_{AL} = N-NO_{3fert} + N-NO_{3prec} + N-NO_{3nitrif} + N-NO_{3irr} + N-NO_{3min} - N-NO_{3upt} - N-NO_{3dn} \quad (58),$$

where

$N-NO_{3fert}$ is the applied $N-NO_3^-$ as mineral fertilizer,

$N-NO_{3prec}$ is the contributed $N-NO_3^-$ by rainfall,

$N-NO_{3nitrif}$ is the contributed $N-NO_3^-$ by soil ammonium nitrification,

$N-NO_{3irr}$ is the applied $N-NO_3^-$ with the irrigation water,

$N-NO_{3min}$ is the mineral $N-NO_3^-$ of the soil layer at the beginning of the month,

$N-NO_{3upt}$ is the crop $N-NO_3^-$ uptake, and

$N-NO_{3dn}$ is the denitrified $N-NO_3^-$ in the soil.

References

- Allen RG., Pereira LS., Raes D., Smith M., 2006. Evapotranspiración del cultivo: Guía para la determinación de los requerimientos de agua de los cultivos. Estudio FAO: riego y drenaje, FAO #56. Roma.
- Berghuijs-van Dijk JT, Rijtema PE, Roest. C.W.J 1985: ANIMO: Agricultural nitrogen model. NOTA 1671: Institute for Land and Water Management Research Wageningen.
- Brisson, N., Mary, B., Ripoche, D., Jeuffroy, M.H., Ruget, F., Nicoullaud, B., Gate, P., Devienne-Barret, F., Antonioletti, R., Durr, C., Richard, G., Beaudoin, N., Recous, S., Tayot, X., Plenet, D., Cellier, P., Mached, J.-., Meynard, J.M., Delécolle, R. 1998. STICS: A generic model for the simulation of crops and their water and nitrogen balances. I. Theory and parameterization applied to wheat and corn. *Agronomie* 18, 311-346.
- De Paz JM., Delgado JA., Ramos C., Shaffer MJ., Barbarick KK., 2009. Use of a new GIS nitrogen index assessment tool for evaluation of nitrate leaching across a Mediterranean region. *J. Hydrology* 365:183-194.
- De Paz, JM., Ramos, C., Visconti, F. 2022a. NITIRSOIL: a model for site-specific nitrogen management of Mediterranean vegetable crops (under writing).
- De Paz, JM., Ramos, C., Visconti, F. 2022b. Estimation of the critical nitrogen dilution curve and dry matter production parameters for different vegetable crops under Mediterranean conditions. *Scientia Horticulturae* (submitted).
- Delgado JA., Shaffer MJ., Hu C., Lavado R.S., Cueto J., Joose P., Li X., Rimski-Korsakov H., Follett R., Colon W., Sotomayor D., 2006. A decade of change in nutrient management requires a new tool: A new nitrogen index. *Journal of soil water conservation* 61:62A-71A.
- Delgado JA., Shaffer MJ., HuC., Lavado R., Cueto J., Joose P., Sotomayor D., Colon W., Follett R., Del Grosso S., Li X., Rimski-korsakov H., 2008. An index approach to assess nitrogen losses to the environment. *Ecological Engineering* 32:108-120.
- Delgado JA., 2020. Nitrate leaching index. En: *Managing Water Resources and Hydrological Systems*, Ed. Edited By Brian D. Fath, Sven E. Jørgensen, Megan Cole. Capt 39. Boca Raton CRC press
- Elia A, Conversa G. 2015. A decision support system (GesCoN) for managing fertigation in open field vegetable crops. Part I—methodological approach and description of the software. *Frontiers in Plant Science*, 6, 319.
- Gallardo, M., Thompson, R.B., Giménez, C. Padilla, F.M., Stöckle, C.O. 2014. Prototype decision support system based on the VegSyst simulation model to calculate crop N and water requirements for tomato under plastic cover. *Irrigation Science*, 32, 237–253.
- Gilmour JT. 1984. The effects of soil properties in nitrification and nitrification inhibition. *Soil Sci. Soc. Am. J.* 48:1262-1266.
- Hansen S., Jensen H.E., Shaffer M.J. 1985. Development in modelling nitrogen transformations in soil. In: *Nitrogen Fertilization in the Environment*, Ed. Bacon PE, Marcel Dekker inc. New York, Basel, Hong Kong. Chpt 3: 83-107.

- Hénault, C., Bizouard, F., Laville, P., Gabrielle, B., Nicoullaud, B., Germon, J.C., Cellier, P. 2005. Predicting in situ soil N₂O emission using NOE algorithm and soil database. *Global Change Biology*, 11, 115-127.
- Jones, J.W., Hoogenboom, G., Porter, C.H., Boote, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U., Gijsman, A.J., Ritchie, J.T. 2003. The DSSAT cropping system model. *European Journal of Agronomy* 18, 235-65.
- Knisel WG. 1993. GLEAMS Groundwater loading effects of agricultural management systems Version 2.10. University of Georgia, Coastal Plain Experimental station, biological and agricultural engineering department, publication N. 5, 260 pp.
- Li, Y., Chen, D.L., White, R.E., Zhang, J.B., Li, B.G., Zhang, Y.M., Huang, Y.F., Edis, R., 2007. A spatially referenced water and nitrogen management model (WNMM) for (irrigated) intensive cropping systems in the North China Plain. *Ecological Modelling*, 203(3-4), 395-423.
- Li, C.S. 2012. User's Guide to the DNDC model (Version 9.5). Institute for the study of earth, ocean and space. University of New Hampshire, Durham, New Hampshire (USA).
- Linn DM, Doran JW. 1984. Effect of Water-Filled Pore Space on Carbon Dioxide and Nitrous Oxide Production in Tilled and Non-tilled Soils. *Soil Sci. Soc. Am. J.* 48:1267-1272.
- Marion GW. Black CH. 1987. The effect of time and temperature on nitrogen mineralization in arctic tundra soils. *Soil Sci. Soc. Am. J.* 51:1501-1508.
- Martin de Santa Olalla, De Juan JAE., 1993. *Agronomía del Riego*. Ediciones Mundi-Prensa.
- Meisinger JJ., Randall GW. 1991. Estimating nitrogen budgets for soil-crop systems. En: *Managing Nitrogen for Groundwater quality and farm Profitability*. Capt 5. 85-124. SSSA, Madison, Wisconsin USA.
- Oenema, O., Bleeker, A., Braathen, N.A., Budnakova, M., Bull, K., Cermak, P., Geupel, M., Hicks, K., Hoft, R., Kozlova, N., et al. 2011. Nitrogen in current European policies. In: (Sutton, M., Howard, C., Erisman, J., Billen, G., Bleeker, A., Grennfelt, P., Grinsven, H., Grizzetti, B., Eds.) *The European Nitrogen Assessment: Sources, Effects and Policy Perspectives*, Cambridge University Press: Cambridge, UK, pp. 62–81.
- Oenema O, Brentrup F, Lammel J, Bascou P, Billen G, Dobermann A, Erisman JW, Garnett T, Genovese G, Haniotis T, Hillier J, Hoxha A, Lassaletta L, Jensen LS, Olazabal C, Oleszek W, Pallière C, Powlson D, Quemada M, Schulman M, Sutton MA, Van Grinsven HJM, Vis JK, Winiwarter W. 2016. Nitrogen Use Efficiency (NUE) – Guidance document for assessing NUE at farm level. EU Nitrogen Expert Panel. Wageningen University, Alterra, PO Box 47, NL-6700 Wageningen, Netherlands.
- Rahn CR, K Zhang, R Lillywhite, C Ramos, J Doltra, José Miguel de Paz, H Riley, M Fink, C, Nendel, K Thorup Kristensen, F Piro, A Venezia, C Firth, U Schmutz, F Rayns, K Strohmeyer. 2010. EU-Rotate_N - a European Decision Support System – to Predict Environmental and Economic Consequences of the Management of

- Nitrogen Fertiliser in Crop Rotations. *European Journal of Horticultural Science*. 7(1): 20-32.
- Ritchie J., Singh U., Godwin D., Hunt, L. 1989. A User's Guide to CERES Maize - V2.10. International Fertilizer Development Center P.O. Box 2040 Muscle Shoals, Alabama 35662, U.S.A.
 - Shaffer MJ, Halvorson AD., Pierce FJ. 1991. Nitrate leaching and economic Package (NLEAP): Model description and Application. En: *Managing Nitrogen for Groundwater quality and farm Profitability*. Capt 13:285-322. SSSA, Madison, Wisconsin USA.
 - Shaffer MJ, Delgado JA., 2001. Field techniques for modelling nitrogen management. En: *Nitrogen in the Environment: Sources, problems and Management*. Follett Ed. 391-411. New York, NY: Elsevier.
 - Shaffer MJ, Delgado JA, Gross CM, Follett R., Gagliardi P., 2010. Simulation processes for the Nitrogen loss and environmental assessment package. En: *Advances in Nitrogen Management for Water Quality*. Capt 13:361-372. Ed. (Delgado JA., Follett R.) SWCS, Ankeny, Iowa, US.
 - Stöckle CO, Martin SA., Campbell GS. 1994. CropSyst, a cropping systems simulation model: Water/nitrogen budgets and crop yield. *Agricultural Systems* Volume 46: 335-359.
 - Visconti F. 2009. Elaboración de un modelo predictivo de la acumulación de sales en suelos agrícolas de regadío bajo clima mediterráneo: aplicación a la vega baja del Segura y bajo Vinalopó (Alicante). Tesis doctoral, Universidad Politécnica de Valencia.
 - Visconti, F., de Paz, JM., 2012. Soil, Water and Crop Management for Agricultural Profitability and Natural Resources Protection in Salt-Threatened Irrigated Lands. In: (Ed. Manish Kumar) *Problems, Perspectives and Challenges of Agricultural Water Management*, Chp. 15, pp. 293-310. Intech, Rijeka (Croatia).
 - Visconti, F., de Paz, JM., Martínez, D., Molina, MJ. 2014. Irrigation recommendation in a semi-arid drip-irrigated artichoke orchard using a one-dimensional monthly transient-state model. *Agricultural Water Management*, 138, 26-36.
 - Wagenet RJ, Hutson JL. 1989. LEACHM: Leaching estimation chemistry Model: A process based model of water and solute movement transformations, plant uptake and chemical reactions in the unsaturated zone. Water Resources Institute, Cornell Univ. Ithaca, New York.

Annex I. How to import tables from create **MS Excel**© to **MS Access**©

The step-by-step procedure is as follows:

1. Fill with the data defined by the user in the MS Excel© book “Tables_Nitirsoil_batch.xls. To do this, the user must open the spreadsheet and complete the tables that make up the book with the user's data. Only the data in the columns with red headers is required by the model. Comments have been inserted in each header with explanatory information on the data that must be added to each field. These tables have the same format as is required in MS Access, that is, with the same columns and headers as the “nitirsoil_batch.mdb”. (Fig. A01). This structure should not be changed.

FID	user	profevap_cm	Profundidad de suelo considerada para la evaporacion (cm)	transfer	produccion	Mes_inicial	Mes_plantacion	dia_plantacion	Soil_id	Water_id	climate_id	Crop_id	Irrigat_id	ferti
1	fac_alc_N3_1	15		0	19.58	7	8	26	1	1	46101	39	1	
2	fac_alc_N2_1	15		0	20.63	7	8	26	1	1	46101	39	2	
3	fac_alc_N1_1	15	60 4	0	20.58	7	8	26	1	1	46101	39	3	
4	fac_alc_N0_1	15	60 4	0	19.82	7	8	26	1	1	46101	39	4	
5	fac_alc_N3_2	15	60 4	0	24.35	7	8	22	1	2	46101	40	5	
6	fac_alc_N2_2	15	60 4	0	24.66	7	8	22	1	2	46101	40	6	
7	fac_alc_N1_2	15	60 4	0	21.90	7	8	22	1	2	46101	40	7	
8	fac_alc_N0_2	15	60 4	0	20.00	7	8	22	1	2	46101	40	8	
9	llor_alc_N3_1	15	60 4	0	23.80	7	8	26	2	3	46101	39	9	
10	llor_alc_N2_1	15	60 4	0	23.33	7	8	26	2	3	46101	39	10	
11	llor_alc_N1_1	15	60 4	0	20.57	7	8	26	2	3	46101	39	11	
12	llor_alc_N0_1	15	60 4	0	20.16	7	8	26	2	3	46101	39	12	
13	llor_alc_N3_2	15	60 4	0	22.40	7	7	4	2	4	46101	40	13	
14	llor_alc_N2_2	15	60 4	0	23.29	7	7	4	2	4	46101	40	14	
15	llor_alc_N1_2	15	60 4	0	19.74	7	7	4	2	4	46101	40	15	
16	llor_alc_N0_2	15	60 4	0	17.79	7	7	4	2	4	46101	40	16	
17	mass_alc_N3_1	15	60 4	0	14.56	8	8	13	3	5	46101	39	17	
18	mass_alc_N2_1	15	60 4	0	14.74	8	8	13	3	5	46101	39	18	
19	mass_alc_N1_1	15	60 4	0	15.11	8	8	13	3	5	46101	39	19	
20	mass_alc_N0_1	15	60 4	0	10.61	8	8	13	3	5	46101	39	20	
21	mass_alc_N3_2	15	60 4	0	20.97	9	9	13	3	6	46101	40	21	
22	mass_alc_N2_2	15	60 4	0	20.51	9	9	13	3	6	46101	40	22	
23	mass_alc_N1_2	15	60 4	0	18.75	9	9	13	3	6	46101	40	23	
24	mass_alc_N0_2	15	60 4	0	13.45	9	9	13	3	6	46101	40	24	
25	ESP3_VILL_T4	15	60 4	0	43.87	2	2	23	4	7	319	22	25	
26	ESP3_VILL_T3	15	60 4	0	42.08	2	2	23	4	7	319	22	26	
27	ESP3_VILL_T2	15	60 4	0	40.97	2	2	23	4	7	319	22	27	
28	ESP3_VILL_T1	15	60 4	0	37.50	2	2	23	4	7	319	22	28	
29	ESP2_VILL_T4	15	60 4	0	38.70	2	2	18	5	8	319	22	29	
30	ESP2_VILL_T3	15	60 4	0	37.80	2	2	18	5	8	319	22	30	
31	ESP2_VILL_T2	15	60 4	0	31.10	2	2	18	5	8	319	22	31	
32	ESP2_VILL_T1	15	60 4	0	24.20	2	2	18	5	8	319	22	32	
33	ESP1_VILL_T4	15	60 4	0	23.23	9	9	10	6	9	319	22	33	
34	ESP1_VILL_T3	15	60 4	0	26.05	9	9	10	6	9	319	22	34	
35	ESP1_VILL_T2	15	60 4	0	26.34	9	9	10	6	9	319	22	35	
36	ESP1_VILL_T1	15	60 4	0	26.91	9	9	10	6	9	319	22	36	
37	COL_CH_ESP1_T1	15	60 4	0	69.58	10	10	13	7	10	46101	9	37	
38	COL_CH_ESP1_T2	15	60 4	0	69.79	10	10	13	7	10	46101	9	38	

Figure A01. Data structure for the table “Input_table_main” in MS Excel©

2. Una vez terminado de rellenar los datos en la hoja de calculo y guardado los cambios se debe abrir la base de datos “nitirsoil_batch.mdb” desde donde se quiere importar la hoja de cálculo. A continuación, ir al menú desplegable [Datos externos] → Excel, como se muestra en la Figura A02. Posteriormente se busca el libro de Excel que se quiere importar.

2. Once you have finished of filling the data in the spreadsheet and saved the changes, you must open the “nitirsoil_batch.mdb” database where you want to import the spreadsheet. Next, go to [External Data] drop-down menu Excel, as shown in Figure A02. Subsequently, the Excel workbook that you want to import is searched for.

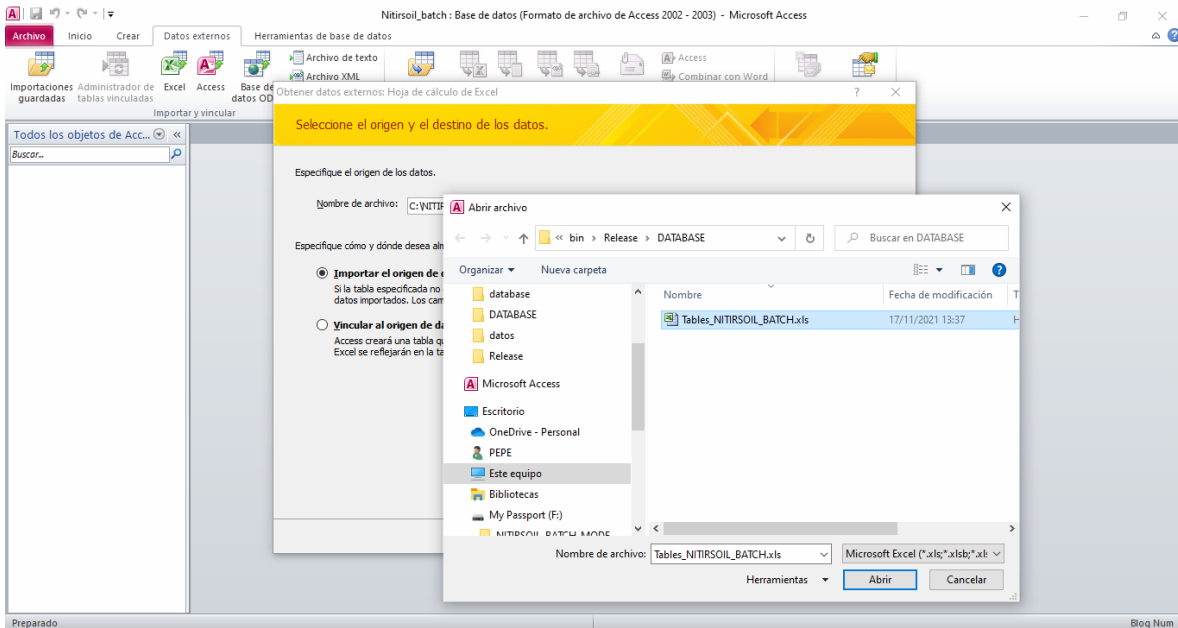


Figure A02. First dialog box Primer cuadro de diálogo para importar tablas desde MS Excel© a MS Access©

3. Next, a spreadsheet import wizard is open and asking which sheet of Excel workbook is the one you want to import. Select it and press the [Next >] button (Fig. A03).

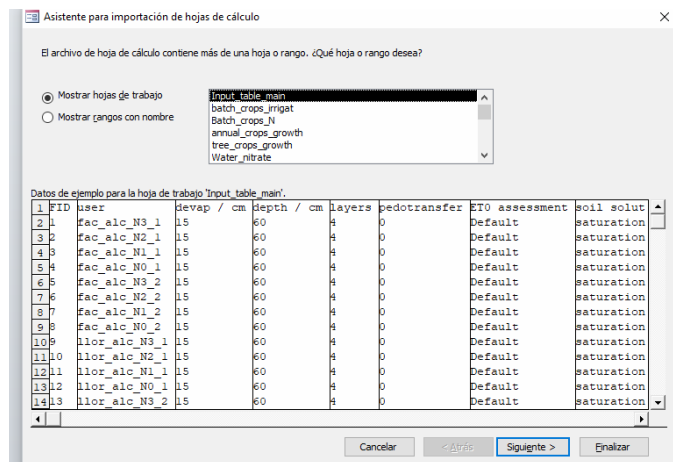


Figure A03. Second dialog box to import tables from MS Excel© to MS Access©

4. Once the sheet has been selected, press the [Next >] button, which will take us to the following dialog box, in which the box must be activated: "First row contains column titles" so that it recognizes that in the first row there are column headers (Fig. A04).

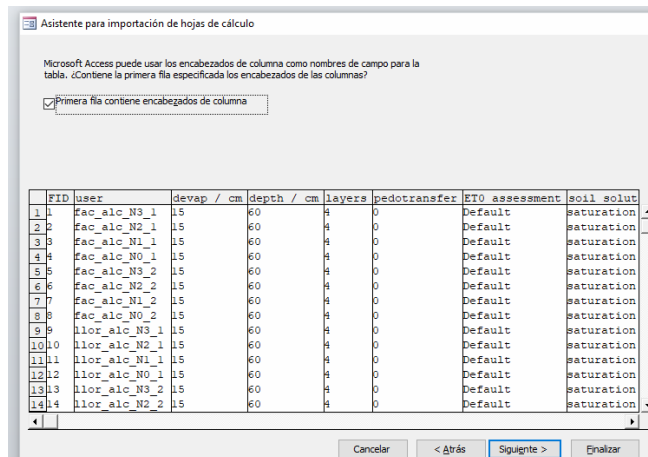


Figure A04. Third dialog box to import tables from MS Excel© to MS Access©

5. Once the [Next >] button has been pressed, the following dialog box will be displayed (Fig. A05). In this dialog select “No” in the “Indexed” drop-down list box, and then press [Next >] button,

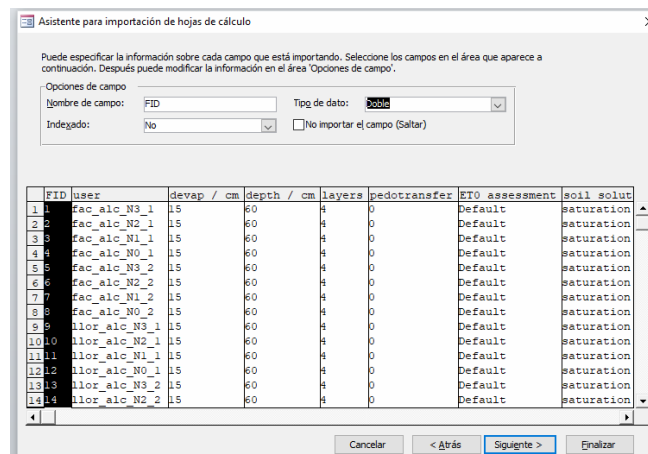


Figure A05. Fourth dialog box to import tables from MS Excel© to MS Access©

6.- In this dialog box, (Fig. A06)., the option “No primary key” must be selected. This way MSAccess will not add an AutoNumber (ID) field to the table imported from Excel. Then press the [Next >] button.

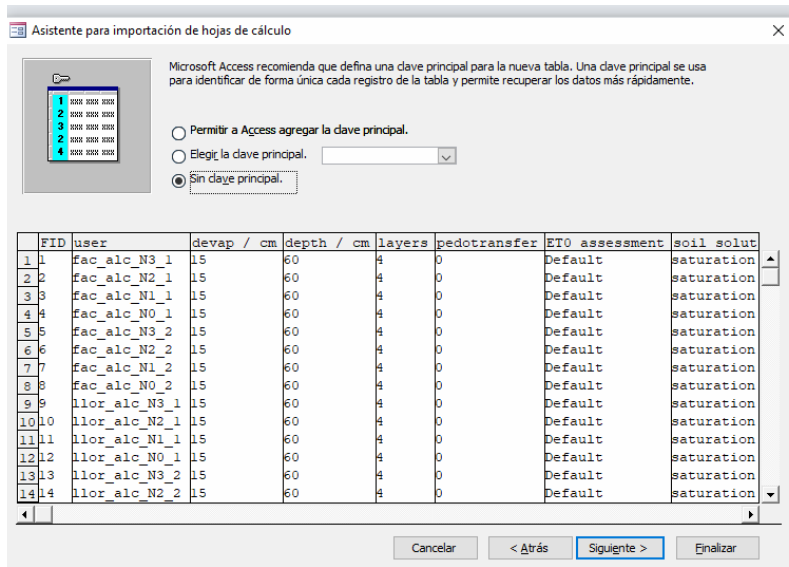


Figure A06. Fifth dialog box to import tables from MS Excel© to MS Access©

7. In this dialog the user must let the MS Excel sheet name be the same name than the MS Access table. In order to finish the process of importing data from MS Excel© into MS Access©, press the [Finish] button. Do not change the table name as the Excel tables already have the names the model needs in the “Nitirsoil_batch.mdb” database.

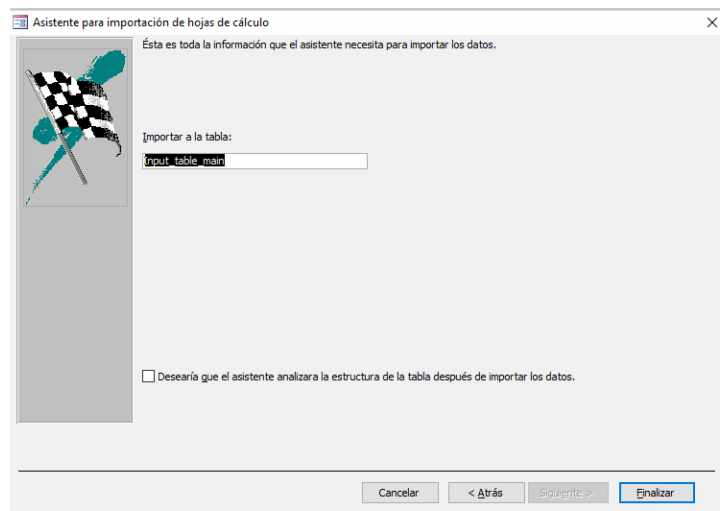


Figure A07. Sixth dialog box to import tables from MS Excel© to MS Access©

Finally, check that the table has been properly created in MS Access© and the data structure is the correct one.