VEGSYST-DSS MANUAL

BRIEF DESCRIPTION OF THE MODEL

The VegSyst Decision Support System (VegSyst-DSS) has been developed to calculate daily N fertilizer and irrigation requirements, and the N concentration of the applied nutrient solution applied for fertigated vegetable crops grown in greenhouses. It can be used for crops grown in soil or in substrate. N fertilizer requirements are based on daily crop N uptake and consider soil mineral N at planting, and N mineralized from manure and soil organic matter. Irrigation requirements are based on estimated evapotranspiration (ETc) and consider irrigation application efficiency and the salinity of irrigation water. ETc can be calculated using the Penman-Monteith equation adapted to greenhouses or the Almeria radiation equation (Fernández et al., 2010; 2011).

VegSyst-DSS has very few inputs, all of which are readily available to farmers and advisors. Data inputs are:

- the readily available climate parameters of daily maximum and minimum air temperature and relative humidity (RH) in the greenhouse, and solar radiation outside the greenhouse,
- the amount of soil mineral N in the root zone at planting,
- details of the most recent manure application
- irrigation layout
- soil characteristics

For the climate data, an internal data base of long term average climate data is used; therefore, there is no requirement to enter climatic data. Recommendations based on long term average climate data are suitable for climates with very low climatic variation between years such as within greenhouses in Almeria. VegSyst-DSS provides a detailed science-based plan of daily N and irrigation requirements that is specific to the characteristics of an individual crop. To fully optimize management, it is suggested that users also use monitoring methods to fine tune N and irrigation management.

VegSyst-DSS is based on the Veg-Syst crop simulation model which calculates daily crop biomass production, critical N uptake and ETc for vegetable crops. The simulation model is driven by thermal time and is adaptable to the variations in greenhouse climatic conditions thereby providing N and irrigation recommendations specific to given cropping conditions such as season, time of planting, and greenhouse design and covering materials. The VegSyst-DSS assumes that crops have no water or nutrient limitations, which is almost always the case with commercial vegetable production in greenhouses.

For a detailed description of the VegSyst simulation model and the VegSyst-DSS, see Gallardo et al. (2011; 2014) and Gimenez et al. (2013)

USING THE VEGSYST-DSS

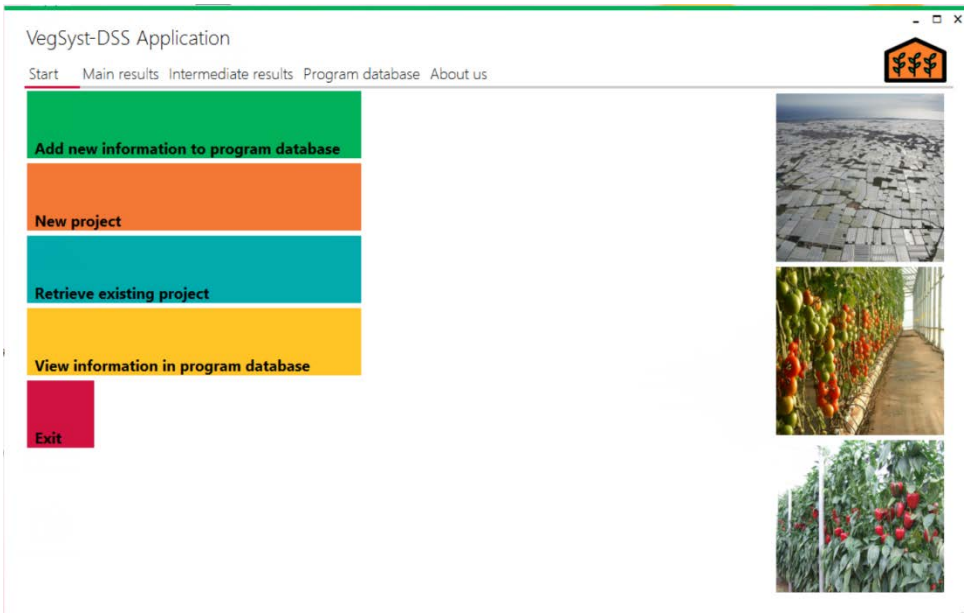
IMPORTANT COMMENT: Before commencing to use the VegSyst-DSS program, the computer on which it will be used must be configured for the

numerical format used in English, of points for decimal points and commas for thousands.

START

The window that appears when starting VegSyst-DSS is the START window (Image 1). There are two options when commencing to use VegSyst-DSS: (1) to create a new project, or (2) to retrieve an existing project created in a previous session.

Image 1. START Window of VegSyst-DSS



Creating a new project

Before creating a new project, it is necessary that all relevant data are included in the program database. A new project refers to a new calculation of irrigation and N requirements for a crop.

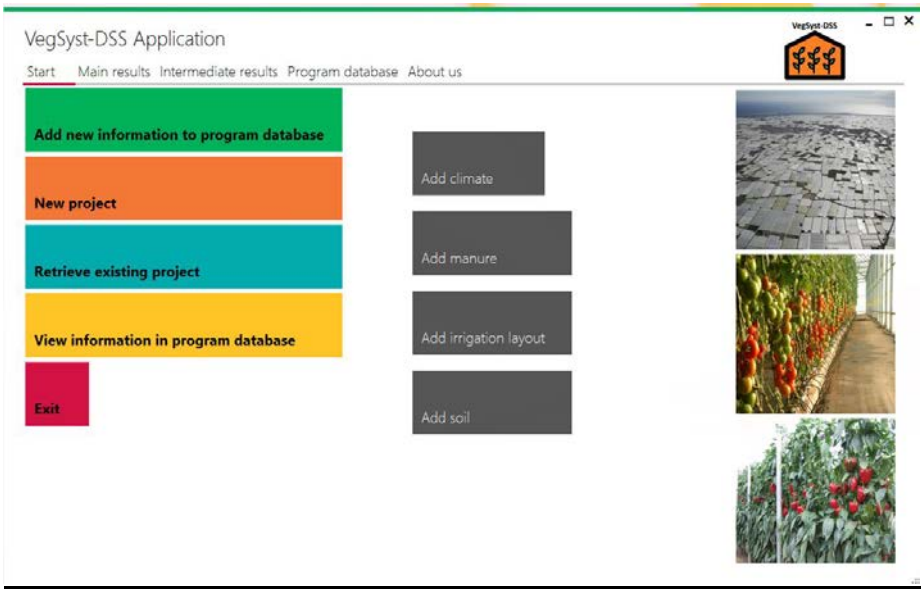
It may be that all of the data required for the new project are available in the database of VegSyst-DSS, having been previously entered or being present as default values. To recover these data, users should select in the New Project windows the appropriate data files from the dropdown menus for climate, soil, irrigation layout and manure.

There may be a requirement to add new information to the program database of climate, manure, irrigation layout and soil characteristics of the crop and/or greenhouse, for which the new project is being prepared.

Add new information to the program database

To add new information, click on the box "Add new information to program database" that is present in the START window. This will then provide four additional boxes of "Add climate", Add manure", "Add irrigation layout", and "Add soil" (Image 2).

Image 2. Add new information to program database window



Add climate: The current version of VegSyst-DSS uses long term average climate data within an individual MS Excel file for each site. For Almeria, the DSS contains a database of long term average meteorological data from the Las Palmerillas Research Station of the Cajamar Foundation located in El Ejido, Almeria (Fernández, et al., 2015). This database appears as the default climate database in the "new project" windows as "CAJAMAR-HISTORICAL". Additional climate files can be added by importing climate in an Excel file using the format of the "ClimateForm" file, given as part of the software (Table 1). The name of the file should indicate the site.

The database contains daily (long term average) values for each day of the year (DOY) of the following climate data for a complete year:

- maximum (Tmax), and minimum (Tmin) temperature, inside the greenhouse,
- daily maximum (RHmax), and minimum (RHmin) relative humidity, inside the greenhouse,
- the daily integral of solar radiation (SR) outside the greenhouse, and
- value of greenhouse roof transmissivity (TR) (ratio solar radiation inside/solar radiation outside) before whitening.

Comment: When the radiation equation is used to calculate ETo, the entry of RH data is required even though the RH values will not be used

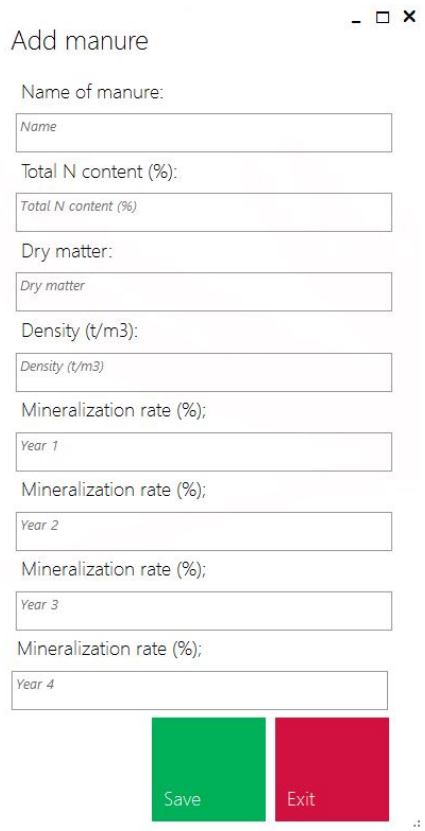
Also, the latitude (degrees, minutes and the hemisphere (N/S)) of the site, where the climate data were obtained, is required. Clicking on the "Add climate" box opens the "Import climate dialog box"; here the user clicks on the box "Import Excel file", and then selects the appropriate Excel file with the required database. All the files of climate data that have been saved within the program will be available for future projects.

Table 1. Format of the Excel file containing the climatic data

Name						
	degrees	minutes	N/S			
Latitude						
DOY	Tmax	Tmin	RHmax	RHmin	SR outside (MJ m^{-2} d^{-1})	TR
1						
2						
3						
4						
5						

Add manure: To add a new manure, the manure form (Image 3) needs to be completed with information of the name, total N content (%), dry matter content (expressed as fraction), density (t m^{-3}) and N mineralization coefficients (%) for years 1, 2, 3 and 4 following application to soil. The N mineralization coefficients are based on the amount of manure N present at the beginning of relevant year, following N mineralization during the previous year. Table 2 presents examples of different manures, most of which were obtained from Schepers and Mosier (1991) that can be used as indicative values.

Image 3. Form to be completed for an additional specific manure.



Example: the mineralization coefficients for the sheep manure commonly used in Almeria are 39%, 22%, 7% and 4% for years 1, 2, 3 and 4 respectively. A N mineralization coefficient for year 1 of 39% indicates that 39% of the initial manure N will be mineralized during the first year. The N mineralization coefficient of 22% indicates that 22% of the manure N present at the start of the second year, will mineralize during the second year. For example for a 50 m^3 ha^{-1} application of sheep manure (0.64 dry matter content, density of 0.7 t m^{-3}) containing 2.2 %N (50x0.7x0.64x2.2x10=493 kg N ha^{-1}), 192 kg N ha^{-1} (39% of 493 kg N ha^{-1}) is mineralized in the first year and 301 kg N ha^{-1} (as organic N) remains at the beginning of year 2 (492.8-192=301 kg N ha^{-1}). During year 2, 66 kg N ha^{-1} will mineralize (22% of 301 kg N ha^{-1}) and become available for the crop.

Daily values of N mineralized from manure are calculated using a potential decay curve (Gallardo et al., 2014). After entering the data describing the manure and then pressing SAVE, the program automatically fits a potential decay curve and calculates the fitting coefficients that fit a potential decay curve to N mineralization coefficients. After pressing

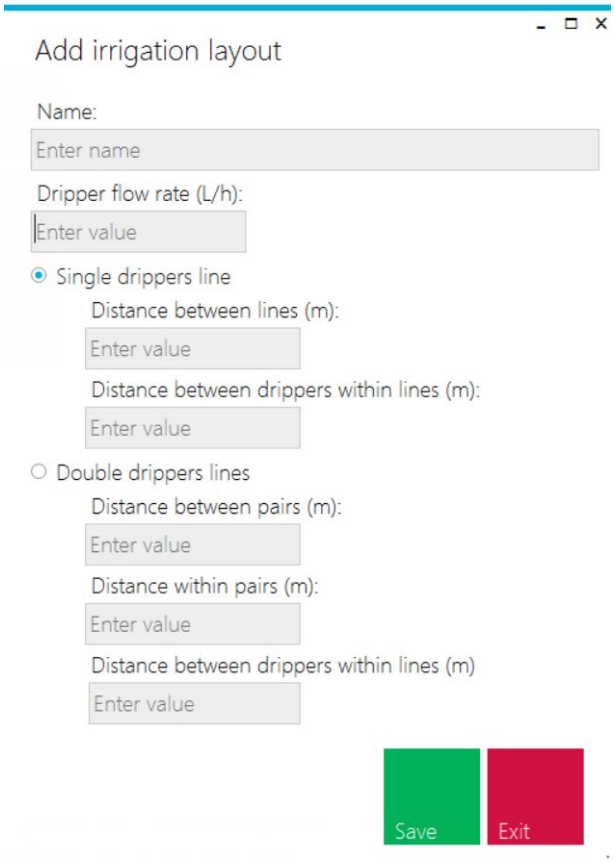
SAVE, all the information entered in the manure form and the fitting coefficients are recorded in the program database and can be used in future projects. In the database of the software, a default sheep manure representative of that used in Almeria ("Standar Almería Manure") is provided, and can be retrieved from the section "Type of manure" when a new project is created.

Table 2- N content and annual mineralization coefficients for various animal manures after Schepers and Mosier (1991). For the sheep manure commonly used in Almeria greenhouses, the default values are dry matter content of 0.64 and density is 0.7 t m^{-3}. For other manures, orientative dry matter and density values are that dry matter contents are commonly 0.6-0.7 and density values are commonly 0.3-0.4 t m^{-3} for fresh, 0-4-0.5 t m^{-3} for medium and 0.7-0.8 t m^{-3} for mature manures.

Manure type	Description	Total N content (%)	Mineralization coefficients (%)			
			Year 1	Year 2	Year 3	Year 4
Sheep	Almeria	2.2	39	22	7	4
Poultry-1	hens fresh	4.5	90	10	5	5
Poultry-2	broilers and turkeys, fresh	3.8	75	5	5	5
Poultry-3	broilers and turkeys, aged	3	60	5	5	4
Pig		2.8	90	4	2	2
Dairy fresh		3.5	50	15	5	5
liquid manure Tank		3	42	12	6	4
Beef-1	fresh	3.5	75	15	10	5
Beef-2	dry	2.5	40	25	6	3
Beef-3	dry	1.5	35	15	10	5
Beef-4	dry	1	20	10	5	5

Add irrigation- To create a new irrigation layout, select "Add irrigation"; this information will be recorded in the program database and will be available for future projects. The information required is the name of the file, the dripper flow rate (L h^{-1}) and the configuration of the drippers (Image 4). For the configuration of the drippers, two general options are provided: (1) single lines, and (2) double lines of drippers. In each of these two options, the distances between lines and between drippers are entered. After completion of the irrigation layout form, press SAVE. In the internal database of the software, several irrigation layout configuration commonly used in greenhouses in Almeria are provided and can be retrieved in the irrigation layout menu when a new project is created. The information available in irrigation layout enables calculation of the length of time of individual irrigations from the volume of irrigation that is calculated the program.

Image 4. Form to define the irrigation layout



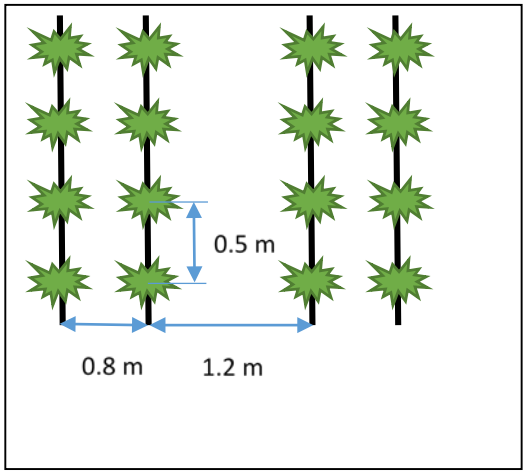
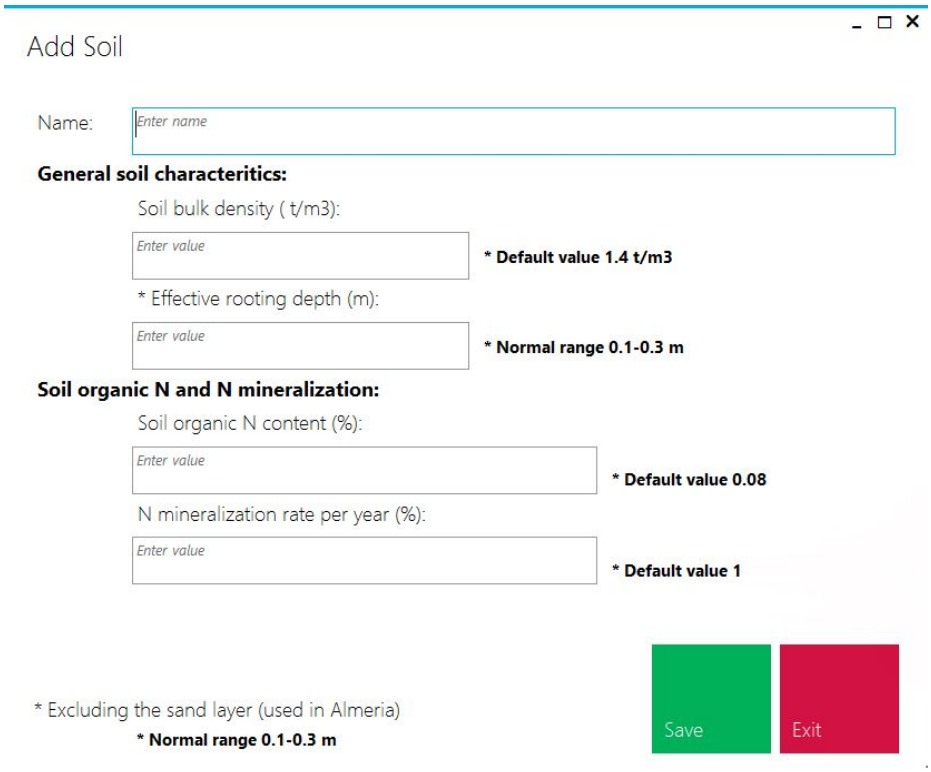


Image 5: Example of a crop with a double line of drippers, with a distance between pairs of 1.2 m, within a pair of 0.8 m and between drippers of 0.5 m

Add soil- The soil information required is: the name of the soil file, general soil characteristics, and information on the soil organic N content and its expected N mineralization rate (Image 6).

The general soil characteristics are: the soil bulk density (t m^{-3}) and the effective rooting depth (m). The effective rooting depth is an estimate of the depth above which most of the roots are located and exclude the layer of sand mulch used in Almeria. The rooting depth is used to calculate the N supplied by various sources of soil N. Default values or normal ranges for greenhouse soils in Almeria are provided. The soil organic N content (%) is an input; these data are part of standard soil analyses. The rate of soil N mineralization from soil organic N is entered as percentage value, i.e. the percentage of soil organic N that mineralizes during one year; a value can be input by the user or a default value of 1% can be used. After completion of the soil information form, press SAVE to record the information. In the internal database of the software, default values for an “enarenado” soil that is representative of greenhouses in Almeria is provided, and can be used when a new project is created.

Image 6. Form with the information of soil characteristics



Once the files of climate, manure, irrigation layout and soil are created, the new project can be prepared.

New Project

To create a new project, the form below (Image 7) has to be completed. The information required is:

- **The name of the project**
- **The size of cropped area (greenhouse)**
- **The cropping media** (options are soil or substrate)
- **The relevant files for climate, soil and irrigation layout are selected**. These can be files that have been created specifically for the new project, files that were previously entered, or default files.
- **The salinity of the irrigation water** (dS m^{-1}) is introduced (Image 8) for crops grown in soil. This is the salinity of the irrigation water; it is not the salinity of the fertigated nutrient solution. For crops grown in substrate, a target drainage fraction should be introduced.
- **Calculation of gross irrigation**: the user has the option to consider, (1) the uniformity coefficient (UC) of the irrigation application system, and (2) the leaching fraction (LF) in the calculation of the gross volume of irrigation as Gross Irrigation= ETc/UC (1-LF). Both, either or neither of UC and LF can be considered. If LF is not to be considered, select “No” in the salinity of irrigation water menu (Image 8); If UC is not to be considered, select “No” in the Consider uniformity coefficient menu (Image 7).

- A value for UC has to be entered in the new project form. For values of UC<0.85, users are strongly encouraged to revise the installation and clean the dripper and pipes to avoid excessive irrigation volumes.

Image 7. Form to complete to generate a new project

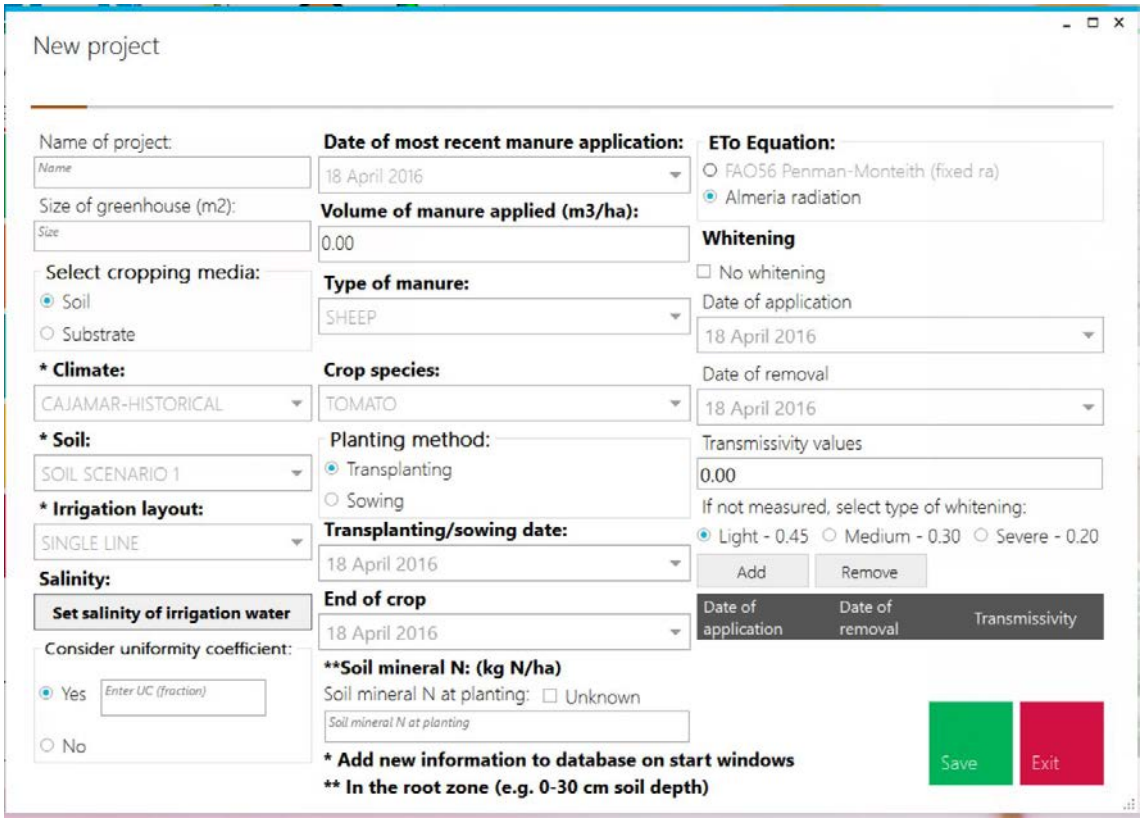
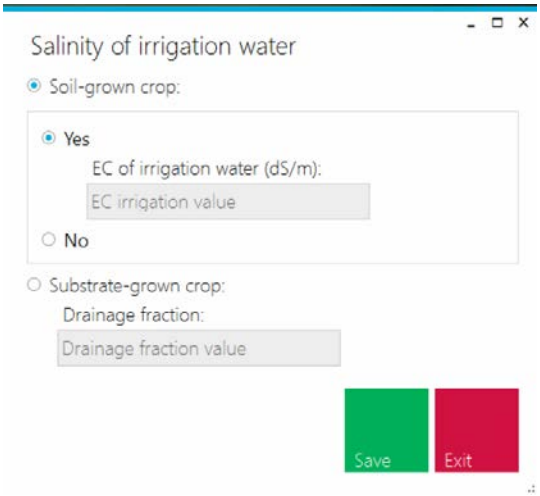


Image 8. Form for salinity management



- **Data related to manure application in the greenhouse** (date of most recent manure application and volume of fresh manure applied as m^3 ha^{-1}). The type of manure is selected from a dropdown menu. Each manure is associated with particular characteristics of N content, dry matter content, density, and of N mineralization. A default file for the sheep manure that is most commonly used in Almeria is provided. Users can select from other files (for different manure types) that they have previously entered or which are part of the original program database.
- **Data related to the crop** are, the crop species selected from a dropdown menu, the planting method (transplanting or sowing) and the dates of transplanting and of the end of the crop.
- **Soil mineral N (kg ha^{-1}) at planting** needs to be entered. Users are encouraged to conduct a soil analysis, at planting, for mineral N in 0-30 cm soil. If this value is not known, tick the box "Unknown".
- **For calculation of ETo, two choices are provided**: a) the FAO56 Penman-Monteith equation adapted to plastic greenhouses in Almeria by considering a fixed aerodynamic resistance (ra) of 295 s m^{-1} and b) the Almeria radiation method. These two equations are described in detail in Fernandez et al. (2010; 2011). For greenhouse in Almeria is recommended the use of the Almeria radiation method.
- Information on the **application of whitening (calcium carbonate suspension) to the greenhouse roof** must be entered. If no whitening is to be applied, tick the box "No Whitening". The dates of application and removal of whitening must be entered, using the calendars provided. A value of roof transmissivity with whitening applied is required. This value can be measured as the ratio of solar radiation inside and outside the greenhouse. If measured values of transmissivity are not available, the user is given a choice of three values according to the thickness of the application (light, medium and severe). After all the relevant information on whitening is introduced, press the bottom ADD to record it in the program. Where several different whitening applications are made to a single crop, they can each be individually entered.

After completion of the entire new project form, press SAVE.

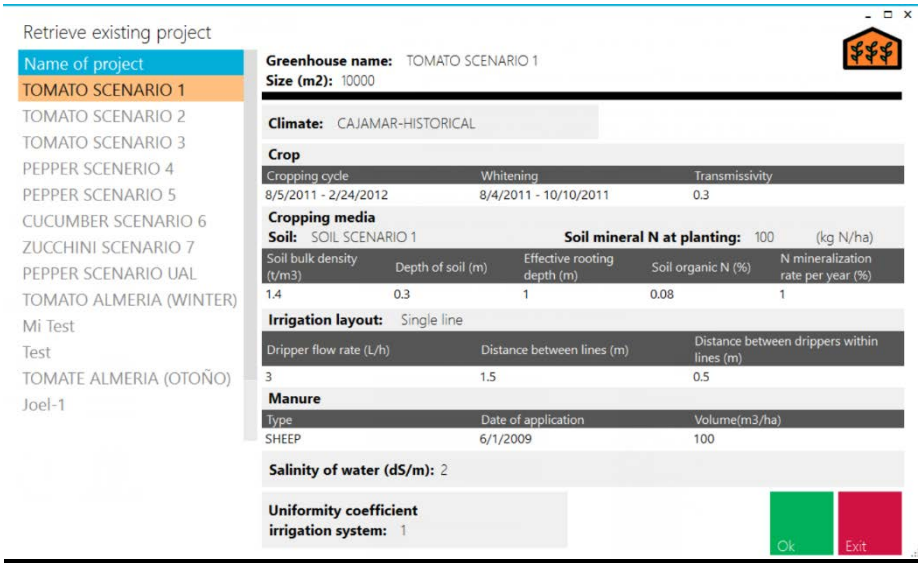
Retrieve existing project

In order to perform the calculations of irrigation and N requirements, a project has to be retrieved from the program database by pressing the button Retrieve existing project (Image 9) located on the START menu. Recently created projects or those created some time previously are all retrieved in the same manner. Pressing this button opens a list with all existing projects in the database of the program. Select the project that you want to work with from within this list, and in the right window a summary of all relevant information of that project will be shown that can be revise to ensure that the correct project is selected.

After selecting the project press OK and the DSS performs the calculations. As an example of the use of this software, a project developed for a tomato crop grown in autumn-winter cycle in Almeria, Spain is provided with the software. This tomato crop a growing cycle from 05/08/2015 to 24/02/2016; whitening of the roof was applied from

transplanting to 15/10/2015; transmissivity during this period was 0.3 (medium level of whitening). The soil was the default enarenado soil for Almeria. An application of 50 m^3 ha^{-1} of manure (of sheep manure typically used in Almeria) was conducted one year before planting and the amount of mineral N in the top 0.2 m of the soil profile at planting was 100 kg N ha^{-1}. The EC of irrigation water was 1.5 dS m^{-1} and the UC of the irrigation system of 0.95. The irrigation layout was 1.5 m between lines of drippers and 0.5 m between drippers.

Image 9. List of existing projects



RESULTS OF THE VEGSYST-DSS

The results are presented in two categories, (1) Main results and (2) Intermediate results. The "Main results" are results required to prepare plans of irrigation and N fertilizer management. The "Intermediate results" relate to the parameters involved in the calculations that may be of interest to users.

The results can be downloaded into a MS Excel file from the Main results window.

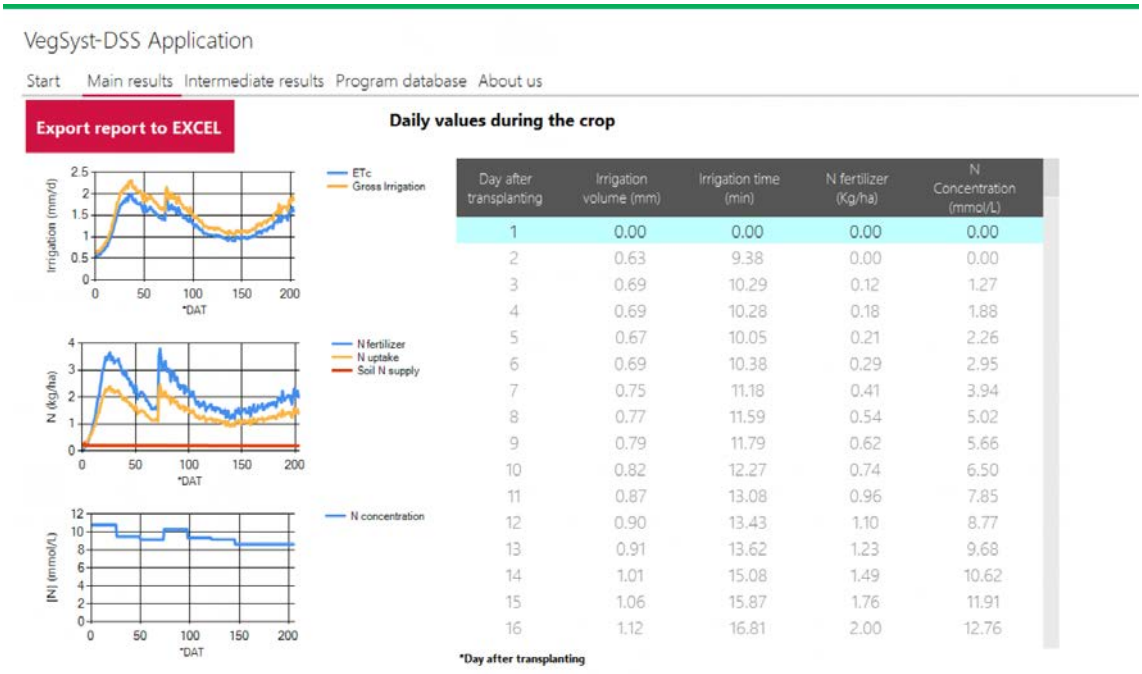
MAIN RESULTS

In the Main results window, the most practical outputs of the VegSyst-DSS are presented in graphs on the left and as daily values in the table on the right (Image 10).

Three graphs are presented:
(1) daily values of gross irrigation requirement and ETc (mm d^{-1}),
(2) daily values of N fertilizer recommendation, crop N uptake and soil N supply (kg N ha^{-1} d^{-1}) (Comment: the soil N supply is N supplied by soil mineral N at planting and N mineralized from manure or soil organic matter)
(3) the recommended N concentration (mmol L^{-1}) for periods of four weeks. This is the average of daily values for four week periods.

Daily values throughout the crop of irrigation volume (mm), irrigation time (min), N fertilizer (kg ha^{-1}) and N concentration (mmol L^{-1}) are provided in the table for each day after transplanting (DAT).

Image 10. Window of Main Results



The results can be downloaded into a MS Excel file from the Main results window. There are two options for downloading results in this format: (1) detailed report and (2) short report. For each type of report, the user can select from a list of parameters, those to be downloaded. The number of options is larger in the case of the detailed report.

The detailed report provides data in four general categories: (1) irrigation requirements, (2) crop N uptake, (3) soil N sources and (4) fertilizer N requirements.

1-Irrigation requirements: Daily values of ETo, kc and ETc, irrigation volume (daily, cumulative and weekly, in mm), and irrigation time (daily and weekly, in minutes).

2- N uptake: daily and cumulative crop N uptake, all in kg N ha^{-1}

3- N sources: Daily and cumulative soil mineral N, daily and cumulative mineralized N and total daily net N supply from the soil, all in kg N ha^{-1}. The net N supply from the soil is the amount that is considered to be available to the crop after considering efficiency factors. For more information see Gallardo et al. (2014).

4- Fertilizer requirements: Daily, cumulative and weekly N fertilizer requirements (kg N ha^{-1}), weekly N fertilizer requirements and N concentration of the nutrient solution (mmol N L^{-1}) and the average N concentration for four week periods

The detailed report also contains a summary of total values for the entire crop of irrigation volume (mm), soil mineral N (kg N ha^{-1}), mineralized N (kg N ha^{-1}) and crop N uptake (kg N ha^{-1}). The total volume of irrigation (m^3) and amount of N fertilizer (as kg of N) for the entire cropped area is also given.

The short report provides data of irrigation volume (daily, cumulative and weekly volume, in mm), irrigation time (daily and weekly, in minutes), and N fertilizer recommendations (daily amount of N fertilizer and the N concentration averaged over four week periods). A summary is provided of total values for the entire crop of irrigation volume (mm), soil mineral N (kg N ha^{-1}), mineralized N (kg N ha^{-1}) and crop N uptake (kg N ha^{-1}). The total volume of irrigation (m^3) and the amount of N fertilizer (as kg of N) for the entire cropped area is also given.

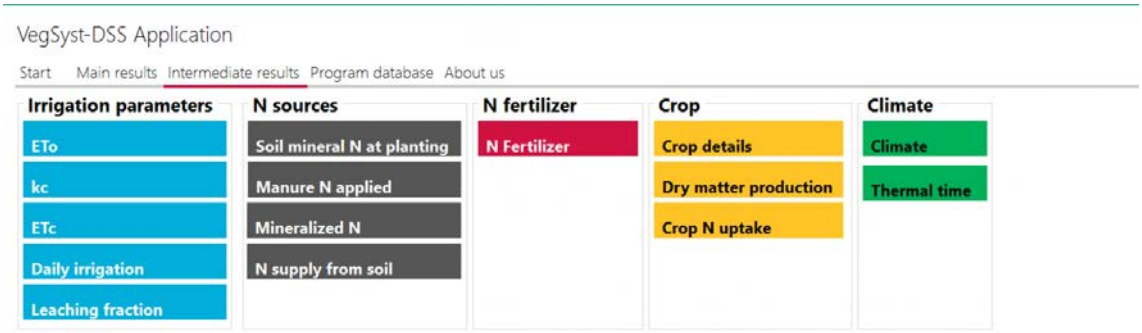
INTERMEDIATE RESULTS

The objective of this section is to present values of intermediate parameters involved in the calculations of the DSS. In the window of intermediate results, these parameters are organized into five general categories: (1) irrigation, (2) N sources, (3) N fertilizer, (4) crop, and (5) climate (Image 11). These categories are organized as separate columns; each category has a different colour.

Within each category, there is a list of individual boxes, each box is for a different parameter (Image 11). Selecting an individual box provides information in graphical format for daily and seasonal trends for the selected parameter.

For some parameters with no seasonal evolution (e.g. leaching fraction, soil mineral N at planting, manure N applied), total or average values are given.

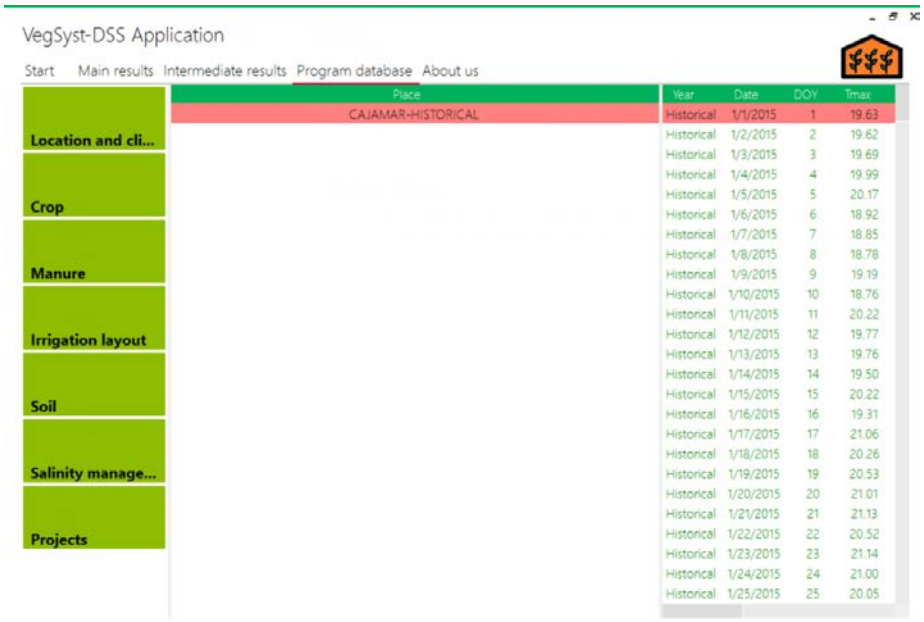
Image 11. Window of Intermediate results



PROGRAM DATABASE

The program database contains all of the databases and files associated to the different scenarios that have been created. The program database is organized into the following categories: (1) Location and climate, (2) Crop, (3) Manure, (4) Irrigation layout, (5) Soil, (6) Salinity management, and (7) Projects (Image 12). In each of these categories, detailed information is provided in the right hand side panel. Projects files can be deleted by selecting the name and using the right hand button of the mouse.

Image 12. Information related to the Program database.



If you have questions about the software or comments, please contact mgallard@ual.es

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REFERENCES

Fernández, M.D., Bonachela, S., Orgaz, F., Thompson, R., López, J.C., Granados, M.R., Gallardo, M., Fereres, E., 2010. Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci. 28, 497–509.

Fernández, M.D., Bonachela, S., Orgaz, F., Thompson, R.B., López, J.C., Granados, M.R., Gallardo, M., Fereres, E., Fernandez, M.D., Lopez, J.C., 2011. Erratum to: Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrig. Sci. 29, 91–92.

Fernández, M. D., López, J. C., Baeza, E., Céspedes, A., Meca, D. E., & Bailey, B. (2015). Generation and evaluation of typical meteorological year datasets for greenhouse and external conditions on the Mediterranean coast. International Journal of Biometeorology, 59(8), 1067–1081.

Gallardo, M., Giménez, C., Martínez-Gaitán, C., Stöckle, C.O., Thompson, R.B., Granados, M.R., 2011. Evaluation of the VegSyst model with muskmelon to simulate crop growth, nitrogen uptake and evapotranspiration. Agric. Water Manag. 101, 107–117. doi:10.1016/j.agwat.2011.09.008

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. Irrig. Sci. 32, 237–253. doi:10.1007/s00271-014-0427-3

Gimenez, C., Gallardo, M., Martinez-Gaitán, C., Stöckle, C.O., Thompson, R.B.B., Granados, M.R., 2013. VegSyst, a simulation model of daily crop growth, nitrogen uptake and evapotranspiration for pepper crops for use in an on-farm decision support system. Irrig. Sci. 31, 465–477. doi:10.1007/s00271-011-0312-2

Schepers, J. S., Mosier, A. R. 1991. Accounting for nitrogen in nonequilibrium soil-crop systems. In: R.F. Follett et al. (Eds), Managing nitrogen for groundwater quality and farm profitability. Soil Science Society of America, Madison, W, USA, pp. 125-138.