IdrAgra tools

User manual

version 4.0

February 2025

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University of Milan

List of Authors and releases

Date	Author(s)	Release description
04/02/2025	Enrico Antonio Chiaradia	Add new functionalities
23/05/2022	Enrico Antonio Chiaradia	Project generation update
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Fabruary 2025

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Requirements

The user should have:

1. a few experiences with QGIS interface (QGIS 3.28 LTR suggested) and some basic knowledge about Geographic Information System
2. the latest version of the IdragraTools plugin installed on its own QGIS environment
3. ~~the Matlab runtime version 9.9 (R2020b) correctly installed~~ no more required
4. some own data to implement the simulation dataset

Conventions

The following conventions are used in the text:

The symbol → represents flow through menu items

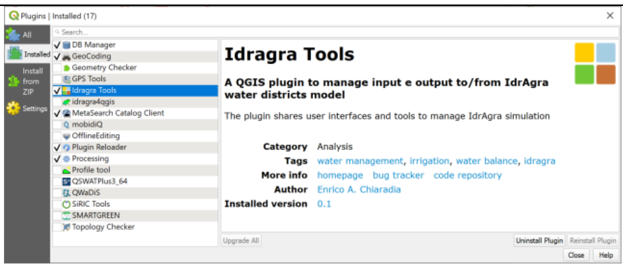
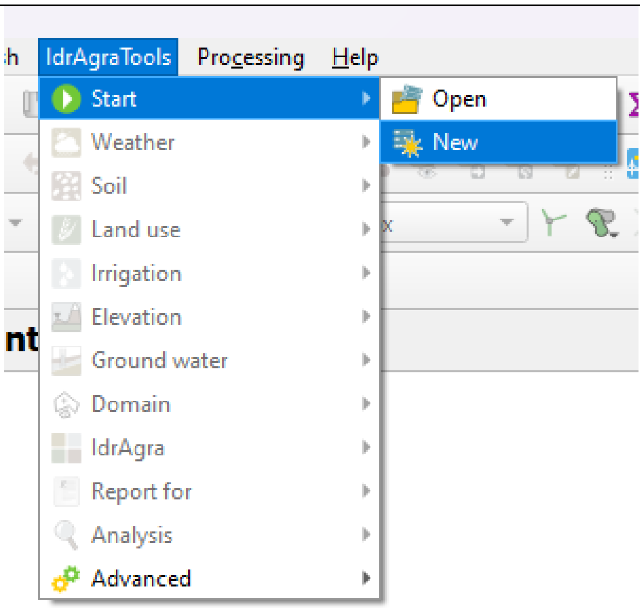
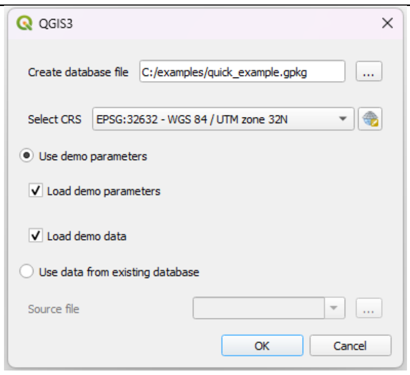
In the text, menu items are in **bold** while attribute names are in *italic*.

This is a warning

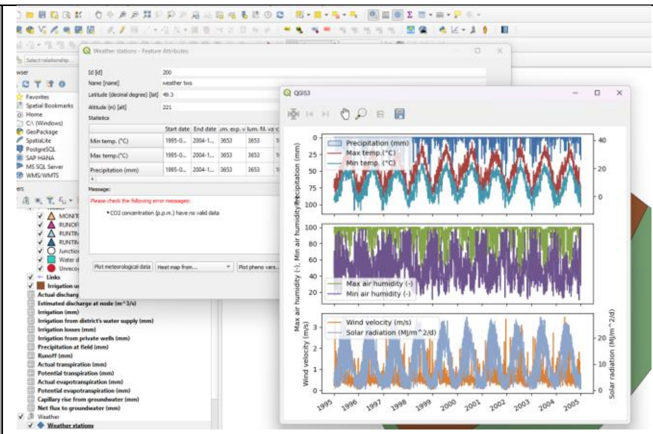
This is a hint

Quick-start tutorial

This quick start tutorial aims to provide the user with an easy guide to testing the software installation and exploring the IdrAgraTools functionalities.

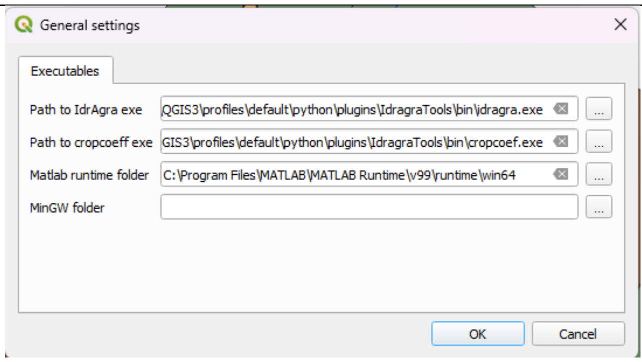
<table>
<tr><td>STEP 1</td><td>
</td><td>Run QGIS and activate the IdrAgraTools plugin</td></tr>
<tr><td>STEP 2</td><td>
</td><td>Under the IdrAgraTools menu, select Start → New. A new dialog will open</td></tr>
<tr><td>STEP 3</td><td>
</td><td>In the new dialog, check the path of the database that will be created, Select CRS (Coordinate Reference System), Load demo parameters and the Load demo data options. In this way, a new working database with some test data is loaded.</td></tr>
</table>

STEP 4



Explore the dataset (e.g. weather data using the QGIS identify feature tool, a custom dialog opens and gives access to statistical and plotting functionalities)

STEP 5

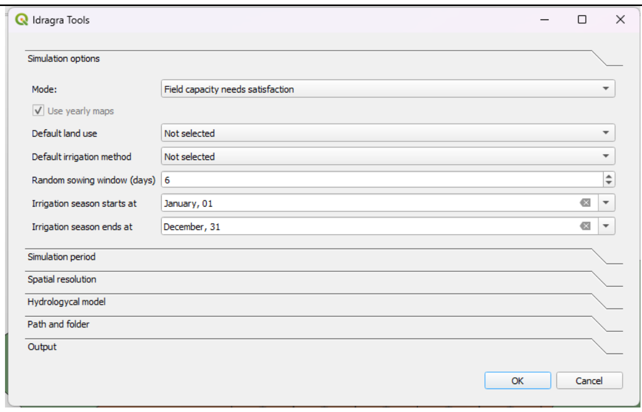


Check the executables paths under the Advanced → Options menu

Idragra executables are stored in the bin folder under the installation path of the plugin.

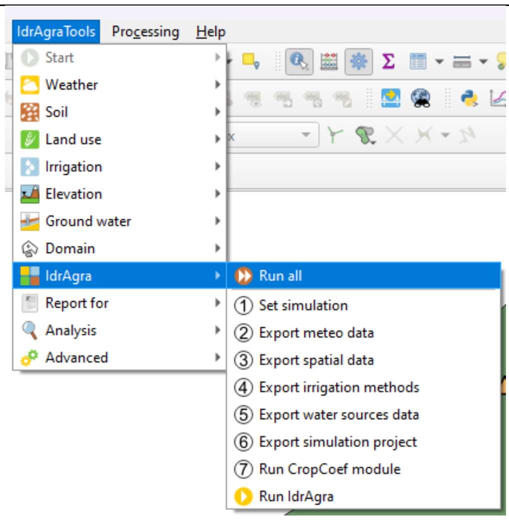
From IdragraTools 2.0, both Matlab and MinGW are no more required.

STEP 6

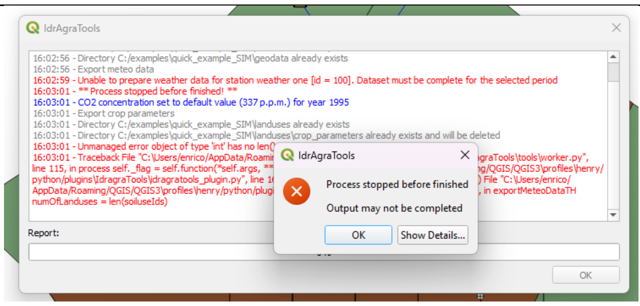


Setup the simulation in Need mode, select the time period (2000), the spatial resolution and calculation domain (e.g. irrigation district) and, finally, choose the outputs steps.

STEP 7

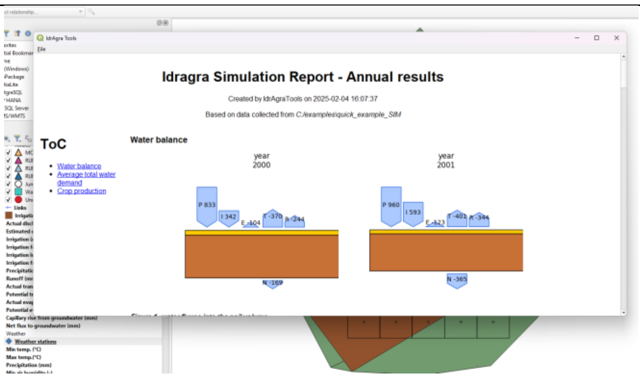


Run the simulation (each single step or all together)



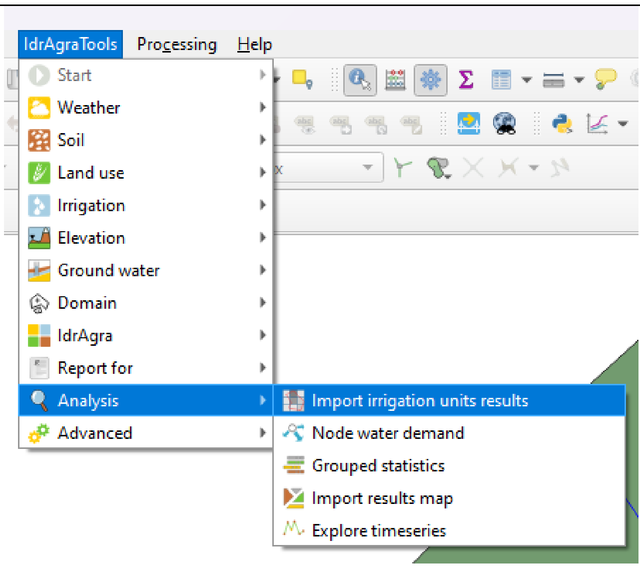
Read the output message (reds are errors) and fix the problem. In this case, just select the correct simulation period (e.g. 2000-2001)

STEP 8



Make one or more reports to check simulation results

STEP 9



Import the results:

Import irrigation units results compute time-average distributed value from the IdrAgra outputs

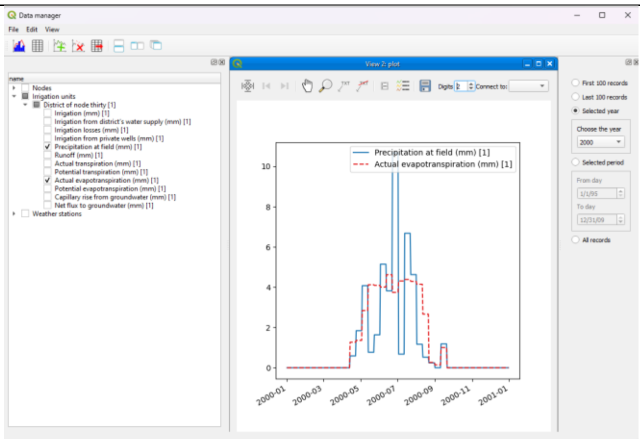
Node water demand calculates estimated discharges at each nodes of the network

Grouped statistics creates maps for each outputs and aggregation edges and functions

Import results map: generate domain based map for the main outputs (available only when *Use domain shape(s) as computing element(s)* is selected)

Explore timeseries opens the Data manager interface

STEP 10



Explore the results. In the **Data manager** interface, select the element (node, irrigation unit or weather station) and the period and add plots to the main view

Detailed tutorial

In the section, all the functionalities implemented in the IdrAgraTools plugin will be described.

For specifics related to the implementation and use of the IdrAgra model, please refer to Technical and User manuals available on www.idragra.unimi.it.

System requirements

IdrAgraTools runs under Windows 7/8/10/11. The following software are mandatory:

- QGIS 3.28 LTR (other versions are not tested and compatibility issues may exist)
- ~~Install Matlab® runtime 9.9~~

Installation

The plugin can be installed directly from the source code available in the zip file that the user can download from www.idragra.unimi.it. Each package version is defined by the release day in the form YYYYMMDD at the end of the file.

The installation procedure consists in the following steps:

1. download the zip file and save it on a user specified path
2. run QGIS
3. from the QGIS interface, under Plugins → Manage and Install Plugins... → Install from ZIP
4. select the downloaded zip file and press the Install Plugin button

After few seconds, the plugin should be successfully installed and ready to run!

The installation package contains also the executables (IdrAgra_XXX.exe and CropCoef_XX.exe) ~~but not the Matlab® runtime necessary for CropCoef that must be installed separately~~

Matlab® runtime is necessary for the old CropCoef executable file now called CropCoef_v4_matlab.exe still available in the installation package

First look to the interface

If the IdrAgraTools plugin is correctly installed, a new menu is added to the main menu bar in the QGIS interface (Figure 1). Note that at the beginning not all the functionalities are activated and the user must start a new simulation project before access to the other items.

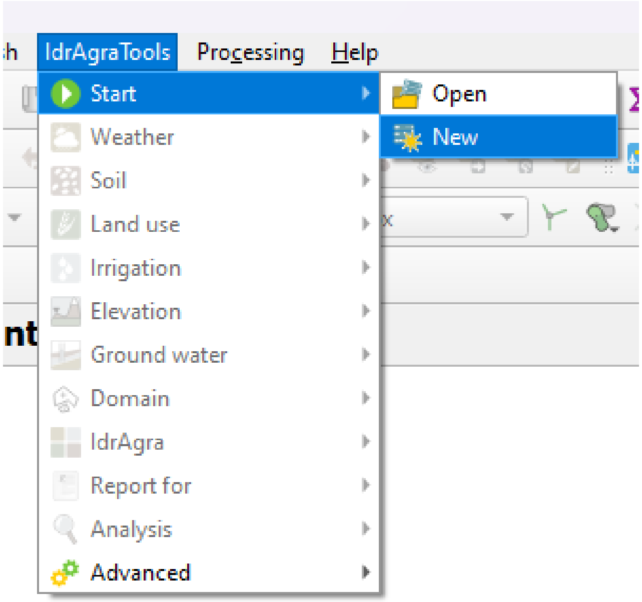


Figure 1: IdrAgraTools menu

Set up the executables paths

Check and complete the paths to the executables. From the QGIS interface, under IdrAgraTools → Advanced → Options (Figure 1). The path to the executables are filled automatically to the latest supported version (Figure 2). Both the path to Matlab® runtime and MinGW library can be left empty as they are no more necessary but are left for previous versions of the executables.

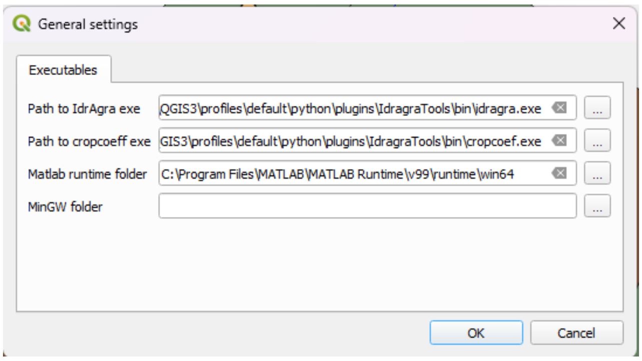
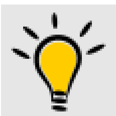


Figure 2: options manager



The paths to IdrAgra and CropCoef executables are prefilled by the system. The user can select another version of the software if necessary.

Under MS Windows® system, the Matlab® runtime path must be complete by the user. On MS Windows® system, commonly it looks like this: C:\Program Files\MATLAB\MATLAB Runtime\v99\runtime\win64

Create a new database

To create a new database, select Start → New from the IdrAgraTools menu. Then, the user can select the path of the database file and the possibility to automatically load test parameters and data.

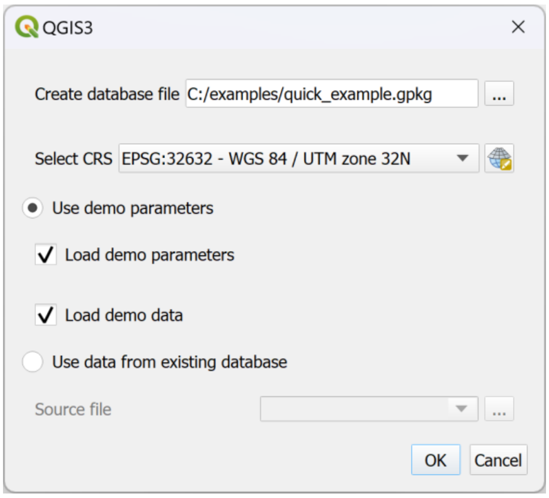


Figure 3: create a new database dialog.

IdrAgraTools uses a geopackage file as local portable database. See Database structure for the complete list of tables included. Geopackage are sqlite file with some GIS attributes and are supported by some other software, other than GIS.

Check "Load demo data" if it is necessary some sample data

Geographic coordinates systems (i.e. polar coordinates) are not supported by the model

Starting from IdrAgraTools 2.0, the QGIS project is automatically generated and saved into the database

Project structure

A bunch of new layers are automatically loaded in the QGIS main window (Figure 4). Layers are organized in groups as reported in Table 1. Most of the maps are vectors layers (points, lines and polygons). Terrain and groundwater elevation are supported as raster maps. In particular, groundwater layer names are dated as they can vary along the time. Timeseries variables (e.g. temperature, precipitation, discharge, etc.) are managed as tables.

Table 1: list of groups and layers generated by IdrAgraTools

Group	Layer/table	Description
Analysis	Control points	Positions for which punctual daily outputs are generated
	XXX	Any layer that will be created by the **Grouped statistics** function
	Irrigation (mm) Irrigation from district's water supply (mm) Irrigation losses (mm) Irrigation from private wells (mm) Precipitation at field (mm) Runoff (mm) Actual transpiration (mm) Potential transpiration (mm) Actual evapotranspiration (mm) Potential evapotranspiration (mm) Capillary rise from groundwater (mm) Net flux to groundwater (mm)	Several tables that will store simulation results
Computing	Domain	The boundaries of the calculation domain (raster mode) or the field where calculations are performed.
Network	Nodes	Points of junction between following links
	Links	Reaches of the network system (e.g. canals, conduits, etc.)
	Irrigation units	Define the area served by a specific water source
Weather	Weather stations	The points that identify weather stations in the study area
	Min temp. (°C) Max temp.(°C) Precipitation (mm) Min air humidity (-) Max air humidity (-) Wind velocity (m/s) Solar radiation (J/m2) CO2 concentration (p.p.m.)	Several tables that will store meteorological variables
Soil	Soils map	The distribution of soil categories
	Soil types	A table with the list of the soils
	Soil profiles	A table with hydrological parameters for each soil layer
Land use	Uses map	The distribution of the soil uses map
	Irrigation methods map	The distribution of the irrigation methods in the study area
	Crop types	A table with different crop parameters
	Soil uses	A table that list soil uses and their characteristics
	Irrigation methods	A table with the list of the irrigation methods characteristics
Elevation	Elevation	One raster map with elevation data [OPTIONAL]
Ground water	Watertable_YYYYMMDD	One or more raster maps with water table elevation. Each map is marked with a specific date in the form year+month+day [OPTIONAL]

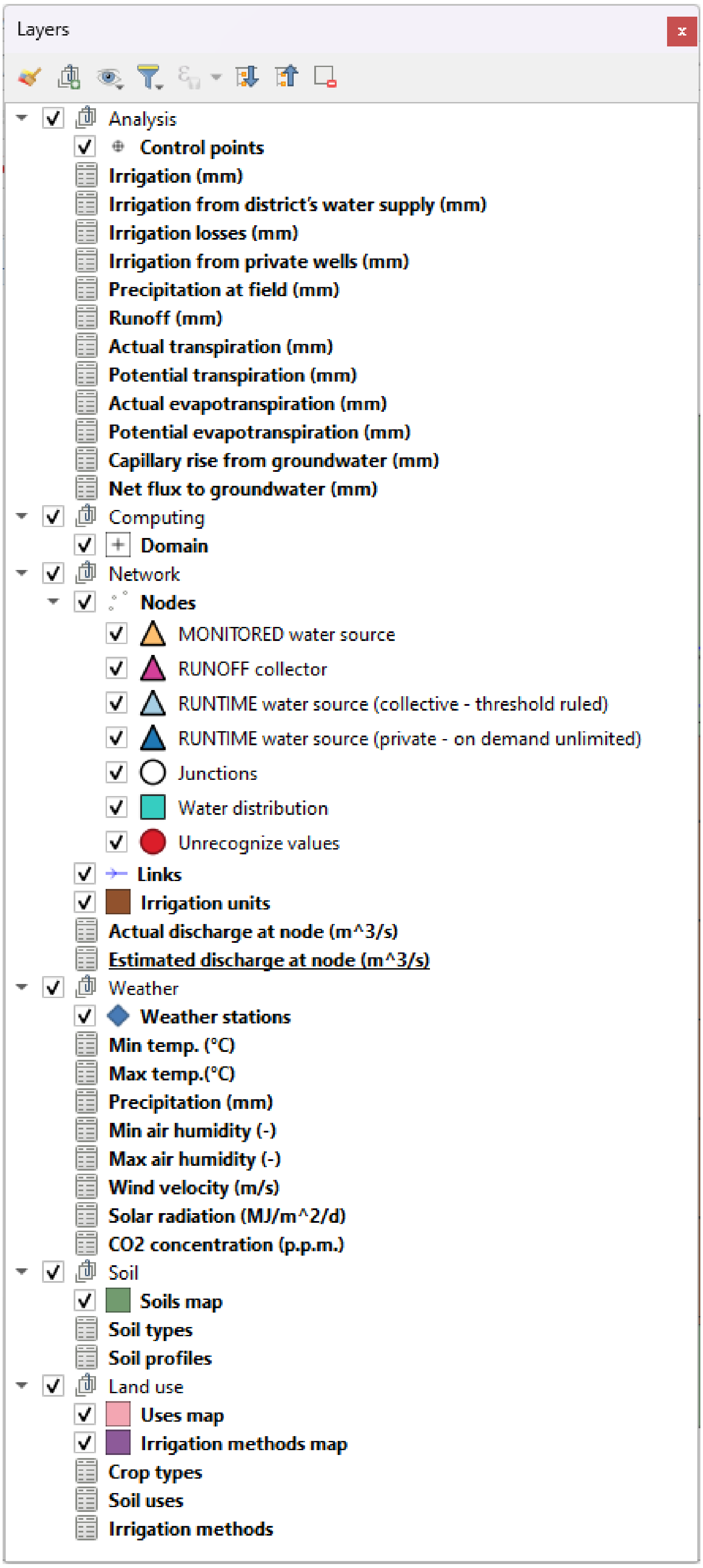


Figure 4: list of layers automatically loaded by IdrAgraTools.

Changes in the layer style don't affect the plugin functionality. Feel free to translates names and assign new styles. Changes will be saved in the QGIS project.

If a required layer is accidentally deleted, it will reloaded when the user opens the project again.

Populate the database

The user can populate the database in several modes, using the functionalities shared by the plugin through the menu items to:

1. import vector maps
2. import raster maps
3. import timeseries

Alternatively, the user can use all the editing tools provided by the QGIS interface and, in particular:

- create a new geometry or edit an existing one
- add row to an existing table
- copy and paste existing elements from other source layer, also in other project

Import vector maps

IdrAgraTools provides some functionalities to import both maps and timeseries:

- To import weather stations position, use IdrAgraTools → Weather → Import weather stations
- To import soil map, use IdrAgraTools → Soil → Import soil map
- To import land use map, use IdrAgraTools → Land → Import land use map [vector]
- To import irrigation units, use IdrAgraTools → Irrigation → Import irrigation units map
- To import irrigation methods distribution, use IdrAgraTools → Irrigation → Import irrigation methods map [vector]
- To import network nodes, use IdrAgraTools → Irrigation → Import node map
- To import network reaches, use IdrAgraTools → Irrigation → Import link map
- To import domain map, use IdrAgraTools → Domain → Import domain

Figure 5 shows an example of the importation form (e.g. soil map) but the procedure is common for all the other cases. In particular, the user can:

a) select the source layer from the already loaded layer or from a file

b) select the corresponding fields from the source layer that match the destination layer attributes (those included in the database)

c) flag save edit if the user wants to automatically save the changes in the destination layer

For the meaning of the name of each field, please refer to the Data structure paragraph

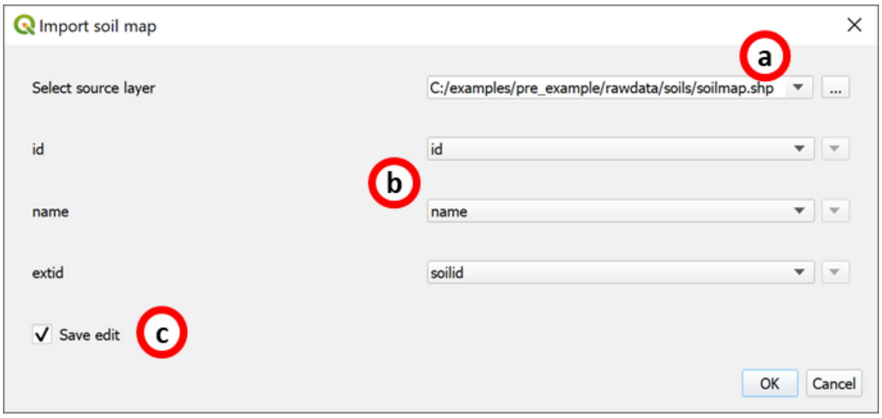
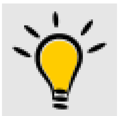
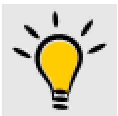


Figure 5: import dialog for soil map. a) select the source layer (from file or already loaded layer), b) match the correct attribute field name, c) check save edit to automatically save changes in the destination layer (i.e. soil map).



The user can always manually edit each vector layer using the editing tools provided by QGIS interface and, in particular, the copy/paste option. In this last case, the fields in common between source and destination layers (i.e. the same name) will be included in the importation process.



Source layer types are those supported by QGIS through the GDAL driver, i.e. Add vector layer

Import raster maps

Raster maps (terrain and groundwater elevation) are imported by the following functionalities:

- To import terrain elevation map, use IdrAgraTools → Elevation → Set/edit elevation map
- To import groundwater map, use IdrAgraTools → Groundwater → Set/edit water table
- To import land use map, use IdrAgraTools → Land use → Set/Edit land use map [raster]
- To import irrigation map, use IdrAgraTools → Irrigation → Set/Edit irrigation map [raster]

Figure 6 shows the set/edit raster map dialog for groundwater layers list. From IdrAgraTools 2.0, the user can import the raster map clipped to the user defined extents.

In the case of groundwater, land use and irrigation methods layers list, the user must set the date associated with the map. The elevation layer is always considered as constant in time, instead.

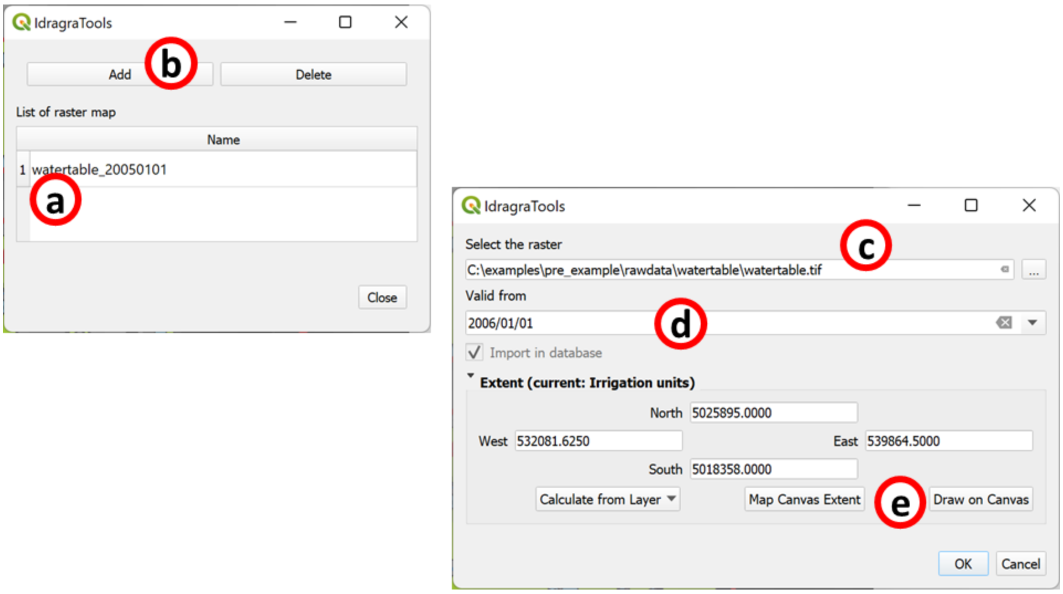


Figure 6: procedure to set water table maps. a) list of loaded maps, b) add a new map button, c) select the source file, d) set the corresponding date, e) select the final extension

Land use and Irrigation method maps can be imported as both vector and raster layer. Pay attention to the associated dates in order to achieve the expected results.

Import timeseries

Timeseries are imported by the following functionalities:

- To import weather data, use IdrAgraTools → Weather → Import meteo data
- To import discharge data, use IdrAgraTools → Irrigation → Import discharge data

In the **Import data** dialog (Figure 7), the user can select the path to the source file, the variable table where to import the dataset, the element to assign the timeseries (a weather station or a network node), the column indexes that define time and value fields respectively, the time format, the number of rows to be skipped and, finally, the string separator. When all the parameters are correctly set, the OK button is enabled and the process can be finalized.

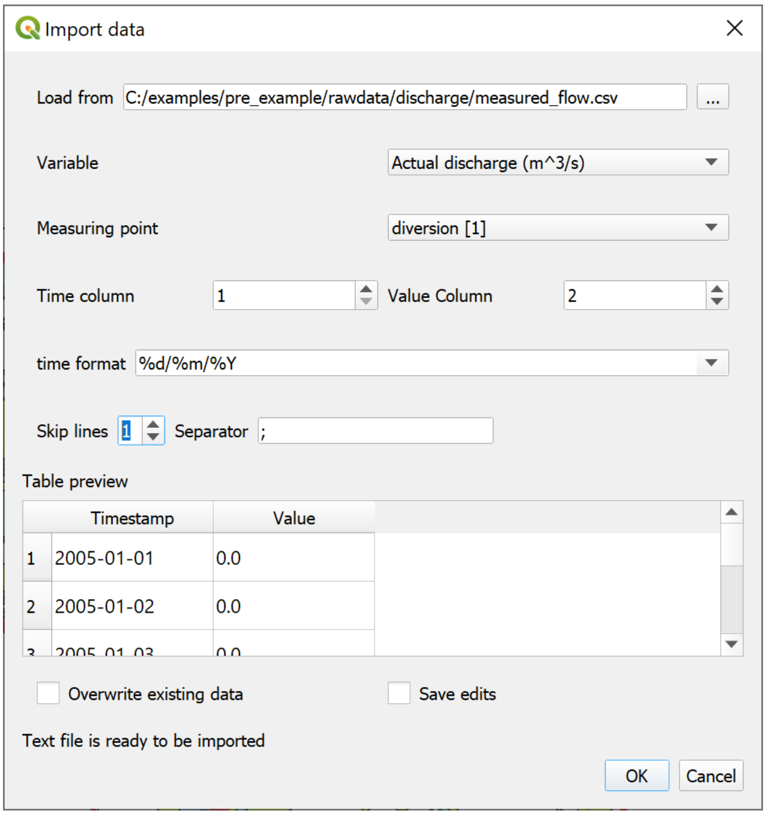


Figure 7: example of timeseries importation dialog.

Large number of weather records can required some time (minutes) to complete the importation process. Consider to use alternative options like "bulk import time series" algorithm or regular SQL command

Create a new geometry or edit an existing one

The user can always access to the standard editing tools of the QGIS interface. To add new features to a vector map layer, simply activate the editing mode, then use one of the editing tools that are now available to add, delete, edit a geometrical feature (Figure 8). As gift, when a new feature is added to one of the layer produced by the IdrAgraTools plugin, a custom form is shown to help the user to complete the required attributes (Figure 8c).

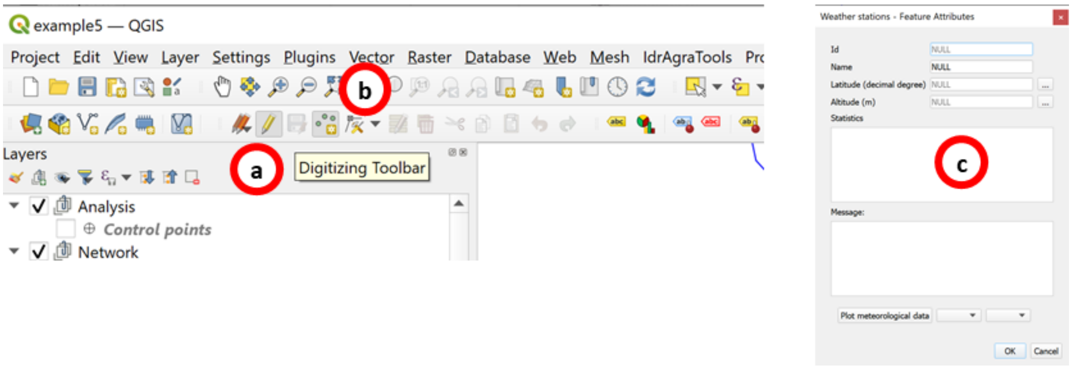


Figure 8: add new feature workflow. a) activate editing mode, b) add new feature, c) complete the required attributed (e.g. weather station form)

Add new parameters row

In case of layer without geometric shape (i.e. tables), the user can add new elements opening the associated attributes table and using the QGIS functionalities. First at all, start editing mode. Then the user can add a new empty row or copy and paste an existing one (Figure 9).

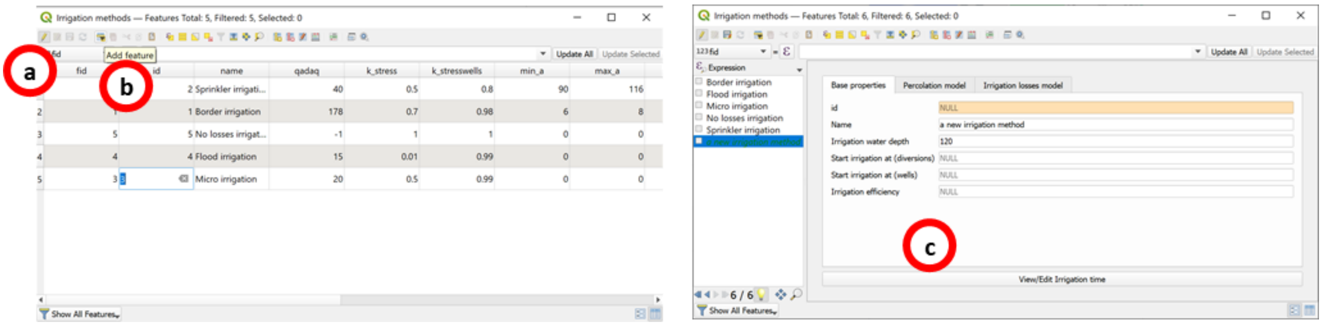


Figure 9: add new record to a parameter table (e.g. Irrigation methods). a) start editing mode, b) add feature, c) switch to form dialog and complete the required attributes.

In the QGIS attributes table, switch to the form view to access to custom dialog with advanced editing features

In the QGIS, select View feature form from the Identify Results tab to access to the custom dialog with advanced viewing features

Use the copy/paste procedure to duplicate an existing record and save time with the attributes filling

Copy/Paste from existing layer

A convenient way to populate the database is copying from existing layers. The user loads into the QGIS project an existing data source (vector layers, spreadsheets, database connection, etc.). Then, the user can select the desired features only (or select all at least) and copy/paste to one of the IdrAgraTools layer. Note that, in order to complete the procedure, the destination layer must be in editing mode and both geometry type and attribute type/name must match between source and destination.

Remember to save the edits in the destination layer after copy/paste

The copy and paste procedure is a convenient way to import all the supported types of source supported by QGIS and in particular delimited text files (e.g. *.txt, *.csv)

Perform simulation

Before start the IdrAgra simulation, the user must complete a sequence of preliminary steps (Figure 10a).

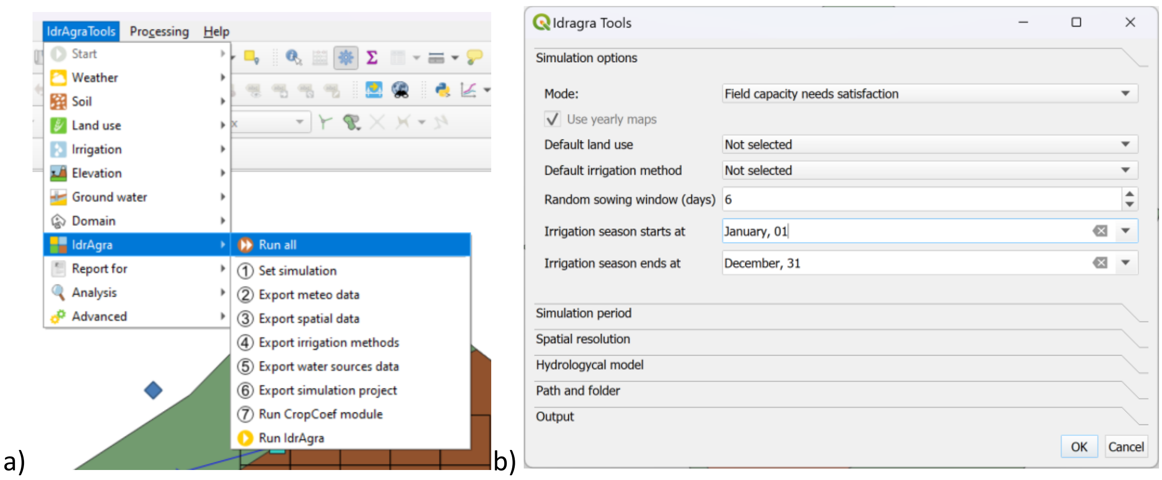


Figure 10: steps to follow to perform a simulation with IdrAgra (a) and the simulation dialog (b)

Set simulation

The Set simulation function opens a new dialog where the user can set all the necessary simulation parameters (Figure 10b). In particular, the user can set:

- **Simulation options**: the simulation mode (Without irrigation, Consumptions, Field capacity needs satisfaction, Fixed volumes) and the starting and ending day of the irrigation period.
- **Simulation period**: select the first and the last year of simulation
- **Spatial resolution**: set the grid cell spatial dimension (in map unit). The maximum extension of the simulation grid is extracted from the extension of the domain layer, independently from its shape. Alternatively, the user can select the “Use domain shape(s) as computing element(s)” option. In this last case, the simulation dataset will refer to the centroid of each element in the domain layer.

- **Hydrological model**: set the thickness of the simulation reservoirs (evaporative and transpirative layer), the capillary rise calculation option and the minimum/maximum values of terrain slope
- **Path and folder**: set the simulation output path
- **Output**: set the time step of aggregation of the model outputs over the simulation period. The user can select to produce monthly outputs or select a different time step.

Export meteo data

This function produces both the weather variables timeseries files, the weather stations table file "weather_stations.dat", the weather weights maps in the geodata folder and the landuse parameters files (Figure 11). When the process starts, a new dialog shows the execution results (Figure 12). If the process concludes successfully, a green message is printed in the dialog and the user can close it. Otherwise, a message advises about execution errors. Warnings and error messages are commonly printed in red.

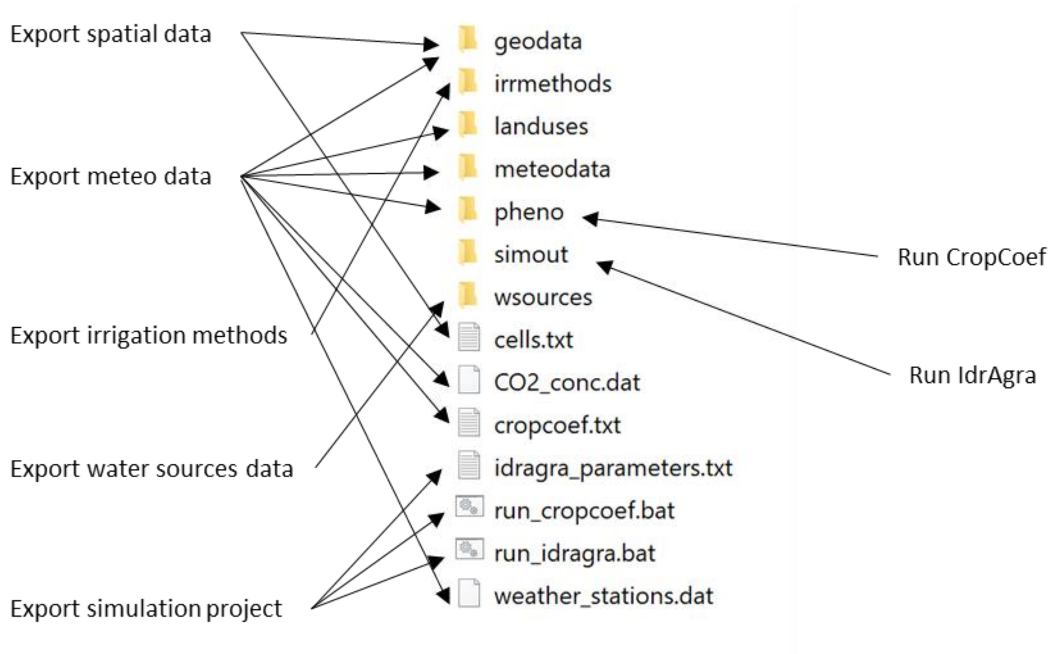


Figure 11: map of produced files and folder against available functions. Files and folder structure is compatible with IdrAgra model requirements.

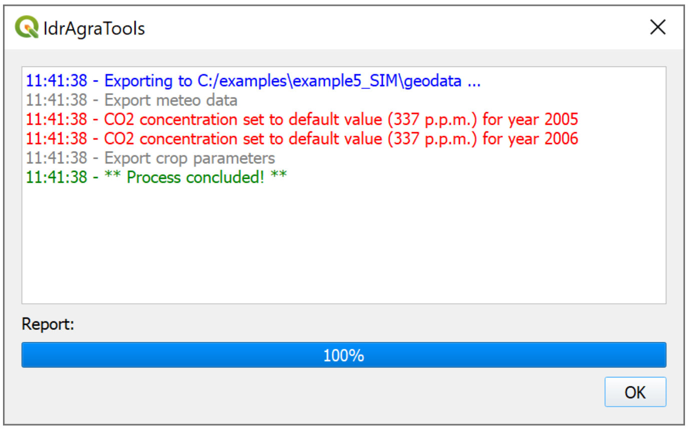


Figure 12: example of exporting procedure calling Export meteo data

Export spatial data

This function produces all the maps required to run IdrAgra simulation. Maps are in raster format as required by IdrAgra (ASCII grid file). All the maps are saved in the "geodata" subfolder. Additionally, also the rice parameter file is added. IdrAgraTools also manages temporal maps (i.e. maps with date associated) for landuses, irrigation methods and groundwater and, consequently the number of files that are produced can vary between different dataset.

IdrAgraTools produces the dataset required by the default version of IdrAgra shared with it. Please, refer to the IdrAgra user manual for details about the meaning of the files and how they should be structured.

Export irrigation methods

This function produces the irrigation methods parameters that are saved in the "irrmethods" subfolder. Irrigation methods parameters derive from the "Irrigation methods" layer in the QGIS project. Each record from the table is saved in a text file named with the "id" attribute.

Export water sources data

This function produces the water source data as required by IdrAgra model. Generated files are saved in the "wsources" folder. In particular, the following files are produced:

- irr_district.txt contains the list of irrigation units with parameters related to "exploration factor" and "private well activation"
- watsources.txt contains the list of irrigation units and the relative water sources (monitored and runtime), competed by attributes (id, type and flow ratio)
- cr_sources.txt stands for collective runtime sources and contain the list of collective sources parameter file

- x.txt (where x is the id of the collective runtime source) are a number of files that report the parameters from collective runtime sources.
- monit_sources_i.txt contains the timeseries of monitored discharges at each source node

IdrAgraTools produces the dataset required by the default version of IdrAgra shared with it. Please, refer to the IdrAgra user manual for details about the meaning of the files and how they should be.

Export simulation project

This function produces the following files in the main simulation folder (Figure 11):

- Idragra_parameters.txt contains all parameters required by the IdrAgra model
- run_cropcoef.bat is the batch executable file for MS Windows environment that contains all the instruction necessary to run CropCoef model
- run_idragra.bat is the batch executable file for MS Windows environment that contains all the instruction necessary to run IdrAgra model

Batch executable files are a convenient way to call IdrAgra modules and executables and are actually used by IdrAgraTools to run simulation

The user can always edits both IdrAgra parameters file and all the *.bat (using a text editor) to match specific needs

Run CropCoef module

This function runs CropCoef module. To do that, the function calls the run_cropcoef.bat file from the simulation folder directly in the QGIS framework. All executable messages are printed in the process dialog similar to Figure 12. By default, CropCoef results are saved in the “pheno” subfolder (Figure 11).

Run IdrAgra

This function launches the IdrAgra model calling the run_idragra.bat file inside the process dialog (Figure 12). All the simulation results are saved in the “simout” subfolder (Figure 11)

Modification in the dataset always requires the application of one or more functions accessible from the IdrAgra submenu provided by IdrAgraTools

The "Run all" option performs all the described functions in one time. Use the single steps procedure to safely conclude the process

Report for

Three pre-formatted documents are available from the IdrAgraTools interface: 1) Simulation inputs overview, 2) Annual outputs totals and 3) Irrigation units outputs (Figure 13).

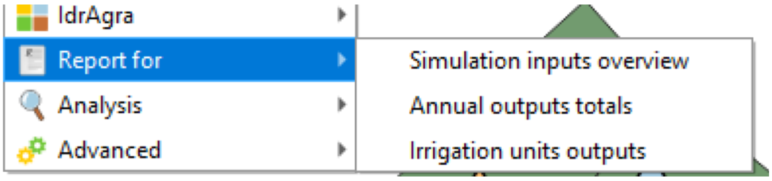


Figure 13: Report for menu group from IdrAgraTools plugin

Reports are generated directly from the IdrAgra simulation project and setup and it partly represents the total amount of information included in the IdrAgraTools database.

If you want to create reports for several simulations, just change the simulation outputs path from the (1) Set simulation → Path and folder tab and repeat the report generation process

Use QGIS functionality if you need to create report for the entire IdrAgraTools project

Simulation inputs overview

The report contains the simulation settings, weather stations position and main statistics of all the time series, list and distribution of land uses, list and distribution of irrigation methods, list, distribution and main characteristics of soil types

Annual outputs totals

The report contains the water balance fluxes expressed as plots and tables, the average total water demand by land uses, irrigation methods and soil types, the crop production (potential biomass and potential and actual yield).

Irrigation units outputs

The report contains the land use distribution, the soil parameters and distribution, the irrigation method distribution, the water fluxes and the crop production for each irrigation units,

Analyse results

Analysis functions are available from 1. the Analysis menu (Figure 14) and 2. the custom Identify feature dialog from Control points layer.

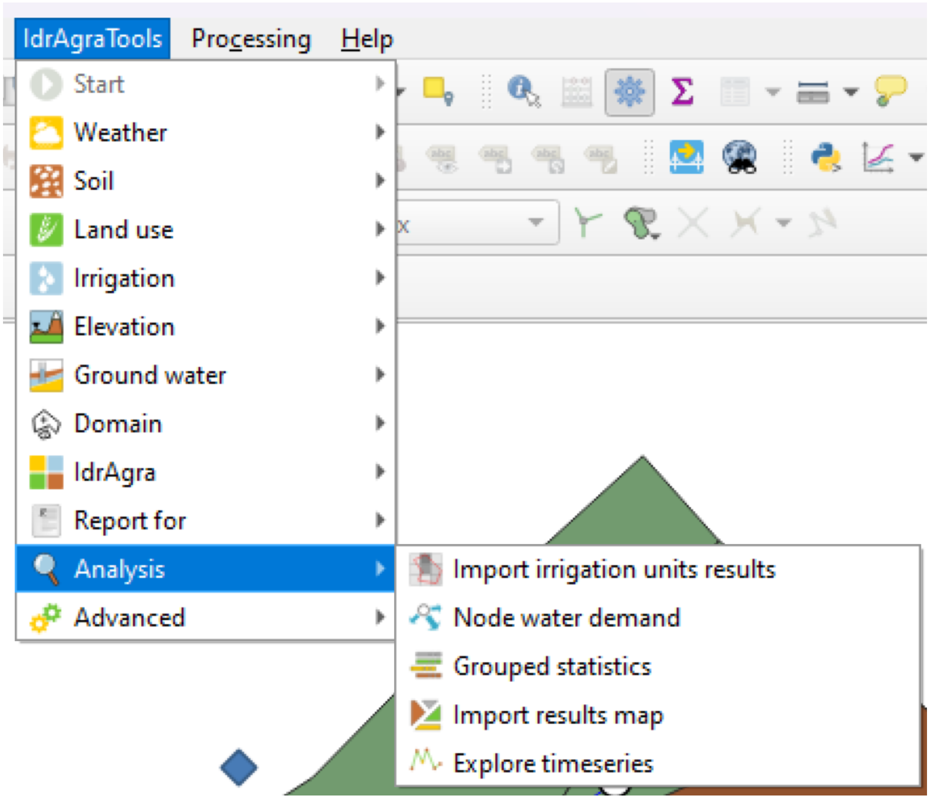


Figure 14: Analysis menu group from IdrAgraTools plugin

Analysis menu options

Import irrigation units results

This function looks for all the output variable maps in the IdrAgra simulation output folder (i.e. simout) and calculates the average values for each Irrigation units defined by the user. As the grid cell is the minimum calculation area in the IdrAgra model, this option applies the mean function to all the cells that are contained in a specific irrigation unit (all the irrigation unit polygons are processed). As outputs are related to a specific date, this information is uniformly distributed to all the days of the simulation period by dividing the mean value by the number of the days between two consecutive outputs steps.

Results are saved in the following tables, already loaded in the QGIS project:

- Irrigation (mm)
- Irrigation from district's water supply (mm)
- Irrigation losses (mm)
- Irrigation from private wells (mm)
- Precipitation at field (mm)

- Runoff (mm)
- Actual transpiration (mm)
- Potential transpiration (mm)
- Actual evapotranspiration (mm)
- Potential evapotranspiration (mm)
- Capillary rise from groundwater (mm)
- Net flux to groundwater (mm)

All the irrigation unit result tables have the following internal structure (i.e. data fields):

- fid: is a progressive value automatically generated by the system (the user won't be care about it)
- timestamp: is the date associated with the result value
- wsid: is the identification code of the irrigation units
- reval: is the value calculated by the process, the meaning depends from the table name

For the meaning of the simulation outputs, please refer to the "Periodic output maps" paragraph of the IdrAgra – Installation and user manual available on www.idragra.unimi.it

Each time this function is called, all the data already imported in the irrigation unit result tables are automatically deleted

The user can always query the result tables by the tools provided by the QGIS framework

Node water demand

This function calculates the discharge requests (always in m^3/s) at each connected nodes of the irrigation network. The process starts from each irrigation units and goes upstream to each node. The algorithm takes into account the losses along each distribution reach (i.e. links) and the ratio of water distributed at each node.

The process has different approach between NEED and USE mode simulation scenario. In the first case, the actual distribution of the water is unknown. The reconstructed discharges are calculated from the irrigation requirements from each irrigation unit and are assigned to the water sources considering the potential delivered maximum discharge (i.e. Summer discharge – *q_sum* attribute of the Nodes layer).

In case of USE mode, instead, as the actual input discharges are known, the function gets the discharge data directly from the IdrAgra output tables (see. Table 30 in the IdrAgra - Installation and user manual) and distributes them along the network.

Function results are always stored in the “Estimated discharge at node (m^3/s)” table that has the following internal structure (i.e. data fields):

- fid: is a progressive value automatically generated by the system (the user won’t be care about it)
- timestamp: is the date associated with the result value
- wsid: is the identification code of each node
- reval: is the discharge value calculated by the process

Grouped statistics

This function produces general purpose maps using a reference geometry as boundary. The user can in fact select the layer to use as a source of shapes (only polygonal geometries are supported), the attribute to identify the features (useful for external linkage or aggregation purposes), the output IdrAgra variables and the function to be applied (Figure 15).

The function result is a new vector map loaded in the Analysis group (see Table 1). Resulting layer has the following associated table structure:

- timestamp: is the date associated to the IdrAgra output map
- wsid: is the code used to identify features
- recval: is the value calculate by the function
- count: is the number of cells selected in each boundary shape

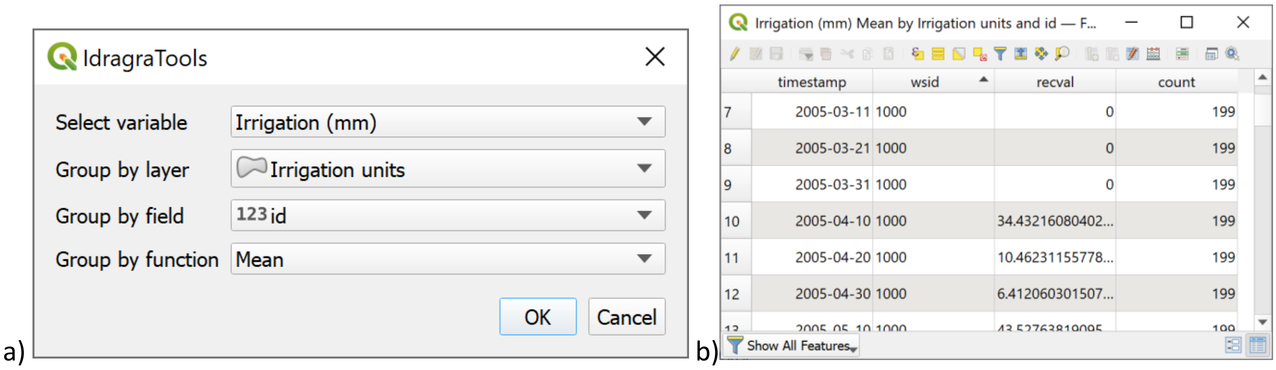


Figure 15: Grouped statistics dialog (a) and attribute table associated with the result (b).

Resulting map is generated as “in memory layer” and all the data will be deleted when QGIS project is close. Export the layer to hard drive before exiting.

The user is free to use whichever layer of type polygon and variable to perform spatial aggregated statistics

Import results map

The function permits to generate maps based on the domain elements and attributes obtained from the simulation. This option is available only when the simulation run under the "Use domain shape(s) as computing element(s)" option.

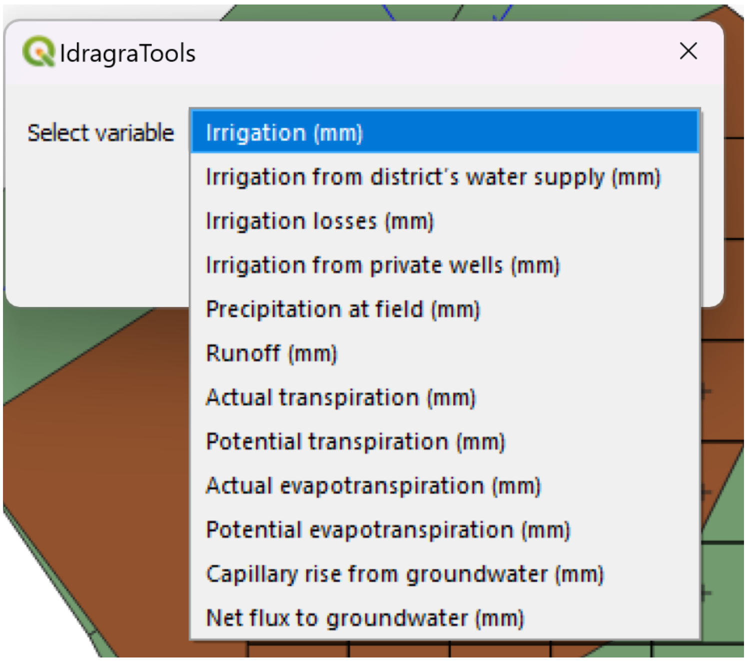


Figure 16: list of variable that can be imported as map.

The map extension will be defined by the domain layer while a different set of attributes will be populated basing on the outputs generated by the model and according to the variable groups (Figure 16) as follow:

- Irrigation (mm): irrigation volumes for each steps and annual totals plus average annual irrigation and number of irrigation events;
- Irrigation from district's water supply (mm): water supplied for irrigation from superficial managed water sources (USE mode);
- Irrigation losses (mm): irrigation losses, if calculated;
- Irrigation from private wells (mm): water supplied by private wells activation (USE mode)
- Precipitation at field (mm): precipitation at fields;
- Runoff (mm): runoff generated at each fields;
- Actual transpiration (mm): actual transpiration volumes for each steps;
- Potential transpiration (mm): potential transpiration volumes for each steps;

- Actual evapotranspiration (mm): actual evapotranspiration volumes for each steps;
- Potential evapotranspiration (mm): potential evapotranspiration volumes for each steps;
- Capillary rise from the groundwater (mm): input volume from capillary rise for each steps;
- Net flux to the groundwater (mm): net flux to groundwater for each steps;

Additionally, the attributes include the identify number [id], the name of the elements [name], the area [area_m2], the id of land use [land_use], soil type [soil_id], irrigation method [irrmeth_id] and irrigation unit [irrunit_id].

Resulting map is generated as "in memory layer" and all the data will be deleted when QGIS project is close. Export the layer to hard drive before exiting.

Explore timeseries

This function permits to access to the "Data manager" framework (Figure 17). The objective of this tool is to share a convenient way to analyse time dependent dataset, generating both graphs and tables (Figure 18).

The base usage of the tool is the following:

a. select one or more variables to plot in the same chart box
b. define the period of time to consider
c. add a new plot to the main view

Alternatively, the user can produce tables instead of charts and export them as comma separated file (*.csv).

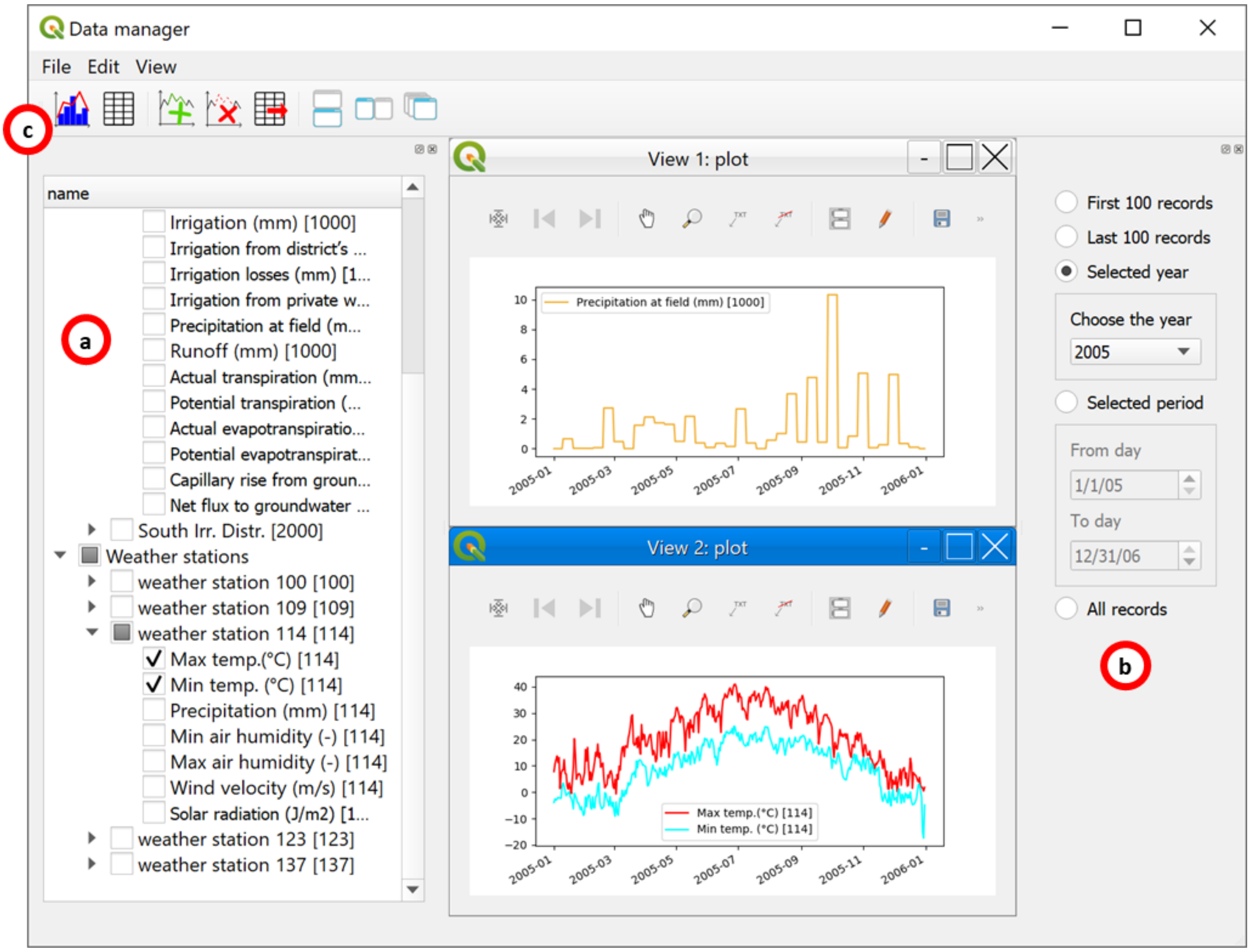


Figure 17: sample view of the Data manager framework; a) select the variable to be plotted, b) select the period to analyze and c) add plot to the main view

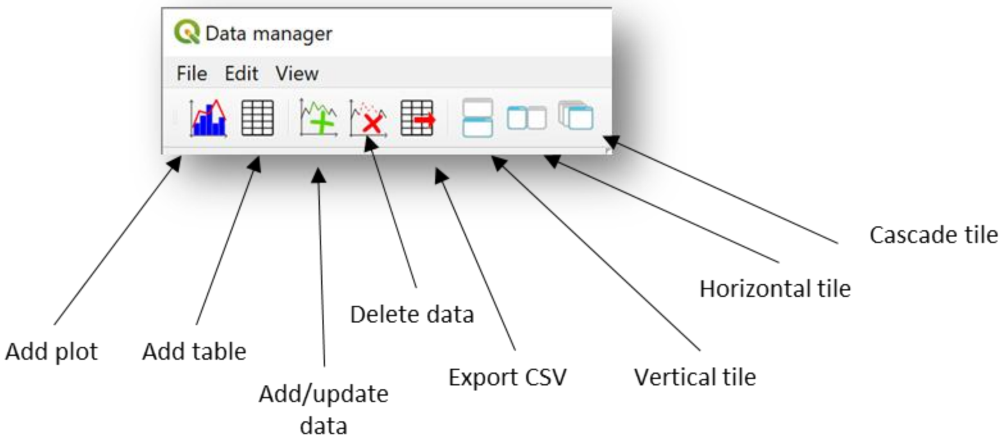


Figure 18: functions available from the Data manager framework

Custom Identify feature dialog of control points layer

If the user has defined Control points (i.e. the position where punctual specific IdrAgra outputs are produced, see cells.txt input file), the simulation outputs are accessible from the custom attributes form generated from each control point (Figure 19 and Figure 20). Results are accessible by the following commands:

- Plot 1^{st} layer WC: generates a chart with the distribution along the simulation period of the soil moisture between the lower and the upper limits (wilting point and field capacity) for the first, evaporative reservoir
- Plot 1^{st} layer vars: generates a chart with the distribution along the simulation period of the volumes (in millimetres) of the main hydrological variables (precipitation, irrigation, interception, runoff, soil water content, evaporation and infiltration) for the first, evaporative reservoir
- Plot 2^{nd} layer WC: generates a chart with the distribution along the simulation period of the soil moisture between the lower and the upper limits (wilting point and field capacity) for the second, transpirative reservoir
- Plot 2^{nd} layer vars: generates a chart with the distribution along the simulation period of the volumes (in millimetres) of the main hydrological variables (1^{st} layer percolation, capillary rise, soil water content, transpiration and deep percolation) for the second, transpirative reservoir
- Plot Irrigation Events: generates a chart with the distribution along the simulation period of the volumes (in millimetres) of the soil water content, irrigation and precipitation, the irrigation threshold and soil water content at field capacity and wilting point of the transpirative layer
- Plot crop vars: generates a chart with the main crop variables (leaf area index, LAI, and crop coefficient, Kc) for the landuse set in each control point.

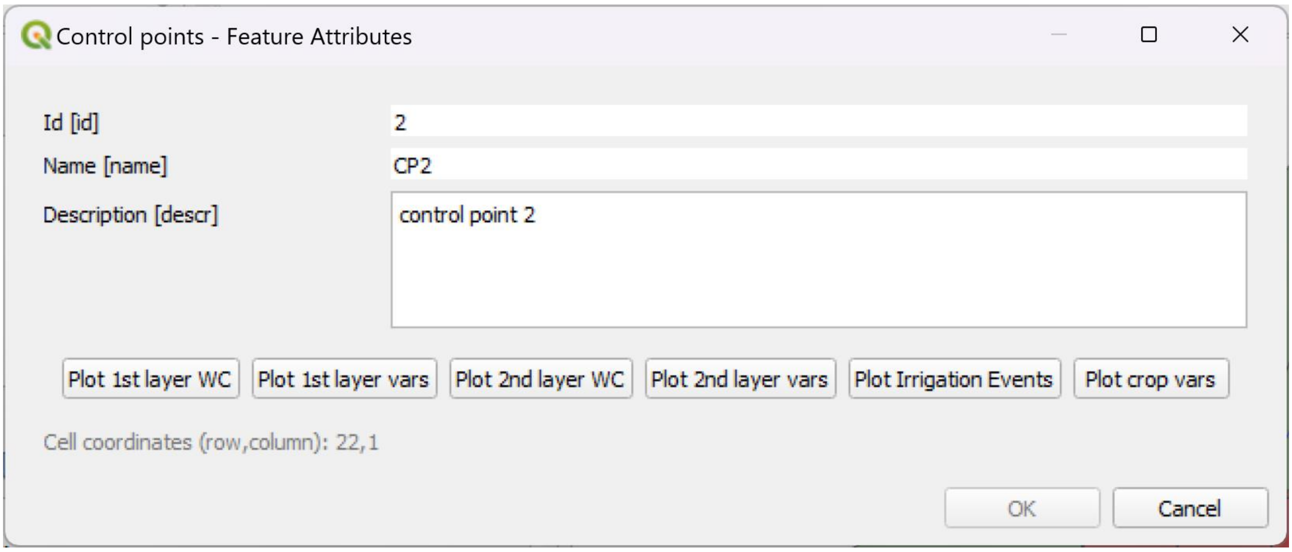


Figure 19: control points attributes custom dialog

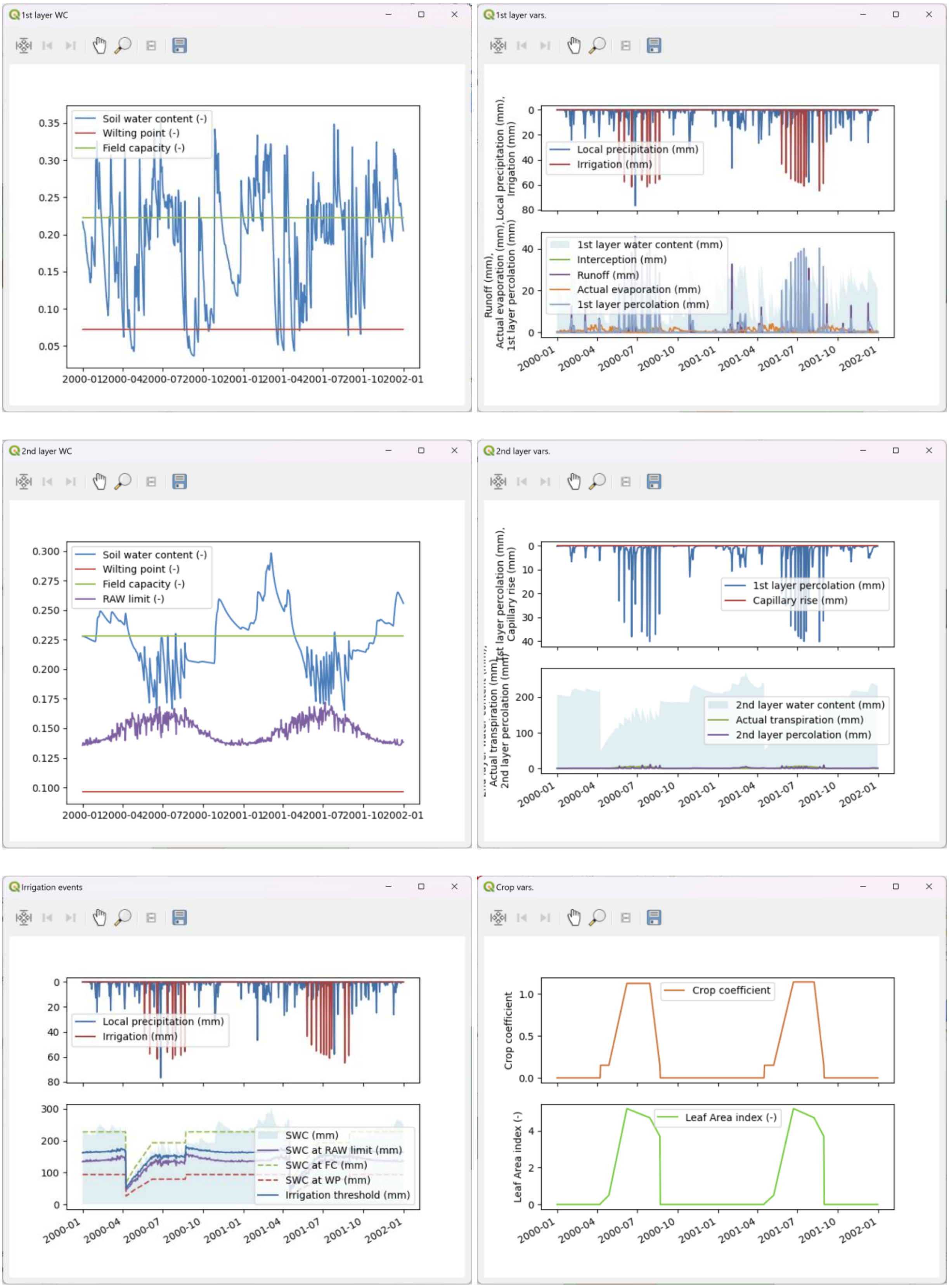


Figure 20: general overview of pre-configurated plots accessible from control points dialog.

Advanced

Algorithm specifications

The IdrAgraTools shares some algorithm in order to produce the file required by IdrAgra model to run and that are not included in the standard QGIS environment. The aim of the following explanation is to give an overview of the logic of each algorithm while the user should refer to the source code for the implementation details.

Weather station weights

Weather station weights maps are created by the following steps:

1. For each weather station in the database, the distance from the centre of each cell is calculated. Then, for each cell, the closest weather station is selected and its *id* was stored. The procedure is repeated up to the maximum number of weather station to consider (5 by default) creating as many weights maps as required.
2. The selected distance is then normalized by the total distance value for each cell so that the sum of weights is equal to one.
3. Finally, the weights map is combined with the corresponding weather station *id* as required by IdrAgra model: the integer part of the stored value is the *id* of the weather station while the decimal part is its weight.

Notice that the spatial resolution of all the resulting maps is defined with the extend and cell size parameters provided by the user.

Slope calculation

Slope map is an input required by IdrAgra and slope values are expressed in percentage. The algorithm has the following steps:

1. Starting from the elevation map in raster format, a clipped version of the elevation map is created based on the simulation extension. Note that the resolution (i.e. cell size) is the same from the original source.
2. Slope is calculated from the clipped elevation map using the native slope algorithm shared by QGIS. Notice that it is expressed in degree units.
3. Native slope is then resampled on the grid cell size set by the user for the current simulation using the mode function . Mode function doesn't take into account for localized difference in slope values that could be caused by artefacts or other data errors
4. Resampled slope map is than transformed from degree to percentage as required by IdrAgra model.

Notice that, if the elevation map is not provided, the slope will be automatically set to zero.

Hydrological soil group assignment

The Hydrological Soil Group, HSG, is a parameter required in the application of the Curve Number method and it is commonly expressed as code from A to D. As characters cannot be stored in raster map (only numerical value are supported), the following HSG-key/value representation is followed:

Hydrological soil response	**HSG-key**	**value**
Low runoff potential when thoroughly wet	A	1
Moderately low runoff potential when thoroughly wet	B	2
Moderately high runoff potential when thoroughly wet	C	3
High runoff potential when thoroughly wet.	D	4

Hydrological groups are assigned following the procedure explained in Mockus, V., Werner, J., Woodward, D.E., Nielsen, R., Dobos, R., Hjelmfelt, A., Hoeft, C.C., 2009. National Engineering Handbook Part 630 - Hydrology, Chapther 7 Hydrologic Soil Groups. United States Department of Agriculture - Natural Resources Conservation Services, Washington D.C.

The method considers the depth to water impermeable layer, the depth to the least transmissive layer and the corresponding hydraulic conductivity at saturation, *ksat*, and the depth to the highest water table (see table 7-1 from Mockus et al. 2009).

The implementation of the procedure consists in the following steps:

1. starting from the table of the soil layers characteristics, a new table is created containing the minimum *ksat* value of selected depth ranges: 0-50 cm, 0-60 cm, 0-100 cm. Also the maximum depth of the soil is calculate, considering also the presence of soil layers with very low *ksat* value ($<10^{-5}$ m/s) or, by default, an impermeable layer at the base of the soil profile.
2. All the parameters created at point 1 are spatially distributed using the soils map and the extent and cell size of the calculation matrix.
3. The conditions grid from table 7-1 in Mockus et al. 2009 is applied. When dual HSGs are present, the less restrictive value is considered under the hypothesis that cropped field are well drained.

Reservoir parameters calculation

As IdrAgra model is based on a double reservoirs criteria, hydrological parameters of each calculation layer must be calculated from soil profiles data as follow:

- *Ksat*, hydraulic conductivity at saturation, is calculated applying the harmonic mean function based on the depths of each soil layers and the reservoir. Harmonic mean function enhances the presence of impermeable layers with lower *ksat* value.
- *Theta_r*, *Theta_WP*, *Theta_FC* and *Theta_Sat*, respectively residual soil moisture, soil moisture at wilting point, soil moisture at field capacity and at saturation, are calculated applying the weighted arithmetic mean based on the depths of each soil layers and the reservoir.
- The Brooks-Corey exponent value, n, is calculated resolving the equation 3.5 from the IdrAgra – Technical manual, using the average soil moisture index previously determined.

All the parameters are then spatially distributed using the soil distribution map over the calculation matrix defined by the user.

Capillary rise parameters

Capillary rise parameters from the model of Liu et al., 2006 (see par. 3.2 in the IdrAgra – Technical manual) are assigned using the most representative texture class.

Soil texture classes are coded according to the USDA classification and aggregated in macro-texture classes in order to match the study cases reported in Liu et al., 2006 as in Table 2.

Table 2: USDA soil texture classification and aggregation to match Liu et al., 2006 model (numerical codes are arbitrarily chosen)

USDA soil texture class	Macro-texture classes to match Liu et al., 2006
1:sand, 2:Loamy sand, 3:sandy loam,	101: Sandy loam soil
4:loam, 5:silt loam, 6:silt,	102: Silt loam soil
7:sandy clay loam, 8: clay loam, 9: silty clay loam, 10: sandy clay, 11: silty clay, 12:clay	103: Clay loam soil

The most representative macro-texture class is then evaluated by the calculation of the average depth weighted macro-texture code of all the soil layers below the maximum calculation volume (i.e. the sum of the depth of the two calculation reservoir), adjusting the thickness of the layers that overlap to calculation volume.

The Liu et al., 2006 parameters from Table 3 are then applied according to the most representative macro-texture class and the soil map distribution.

Table 3: Liu et al., 2006 parameters for each macro-texture class

Parameters	101	102	103
CapRisePar_b1	-0.16	-0.17	-0.32
CapRisePar_b2	-0.54	-0.27	-0.16
CapRisePar_a3	-0.15	-1.3	-1.4

CapRisePar_b3	2.1	6.6	6.8
CapRisePar_a4	7.55	4.6	1.11
CapRisePar_b4	-2.03	-0.65	-0.98

Database structure

Analysis group

Table 4: table from layer Control points [idr_control_points]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the control point	String
descr	Readable description of the control point	String

Domain group

Table 5: table from layer Domain [idr_domainmap]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the control point	String
area_m2	Area of the domain element	Real

Network group

Table 6: table from layer Nodes [idr_nodes]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the node	String
node_type	Type of the node	Integer
q_sum	Summer discharge	Real
q_win	Winter discharge	Real
sum_start	DoY when summer irrigation period starts	Integer
sum_end	DoY when summer irrigation period ends	Integer
win_start	DoY when winter irrigation period starts	Integer
win_end	DoY when winter irrigation period ends	Integer
act_trshold	Activation thresholds (wells)	String
act_ratio	Activation ratios (wells)	String

Table 7: table from layer Links [idr_links]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the link	String
inlet_node	Inlet node ID	Integer
outlet_node	Outlet node ID	Integer
flow_rate	The amount of water that can be drained from inlet note (-)	Real
inf_losses	The amount of infiltration losses (-)	Real

Table 8: table from layer Irrigation units [idr_distrmap]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the irrigation unit	String
distr_eff	Internal distribution efficiency (-)	Real
expl_factor	Multiplier for the irrigation module in Consumption “USE” mode	Integer
wat_shift	Computational shift for irrigation module [NOT USED]	Integer
inlet_node	Inlet node ID	Integer
outlet_node	Outlet node ID	Integer

Table 9: table from layers Actual discharge at node (m^3/s) [node_act_disc], Estimated discharge at node (m^3/s) [node_disc], Irrigation (mm) [stp_irr], Irrigation from district’s water supply (mm) [stp_irr_distr], Irrigation losses (mm) [stp_irr_loss], Irrigation from private wells (mm) [stp_irr_privw], Precipitation at field (mm) [stp_prec], Runoff (mm) [stp_runoff], Actual transpiration (mm) [stp_trasp_act], Potential transpiration (mm) [stp_trasp_pot], Actual evapotranspiration (mm) [stp_et_act], Potential evapotranspiration (mm) [stp_et_pot], Capillary rise from groundwater (mm) [stp_caprise] and Net flux to groundwater (mm) [stp_flux2]

Name	Description	Data type
fid	System defined ID	Integer64
timestamp	Date as YYYY-MM-DD	String
wsid	External ID specific for the associated elements	Integer64
recval	Record value (the meaning depends on the table title)	Real

Weather

Table 10: table from layer Weather stations [idr_weather_stations]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the weather station	String
lat	Latitude (decimal degree)	Real
alt	Altitude	Real

Table 11: table from layers Min temp. (°C) [ws_tmin], Max temp.(°C) [ws_tmax], Precipitation (mm) [ws_ptot], Min air humidity (-) [ws_umin], Max air humidity (-) [ws_umax], Wind velocity (m/s) [ws_vmed], Solar radiation (J/m2) [ws_rgcorr] and CO2 concentration (p.p.m.) [ws_co2]

Name	Description	Data type
fid	System defined ID	Integer64
timestamp	Date as YYYY-MM-DD	String
wsid	External ID specific for the associated elements	Integer64
recval	Record value (the meaning depends on the table title)	Real

Soil

Table 12: table from layer Soils map [idr_soilmap]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the soil area or soil type	String
extid	External ID used to connect soil types and soil profile table	Integer
date	Date associated with the feature [NOT USED]	Date

Table 13: table from layer Soil types [idr_soil_types]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the soil type	String
descr	Description of the soil type	String

Table 14: table from layer Soil profiles [idr_soil_profiles]

Name	Description	Data type
fid	System defined ID	Integer64
soilid	User defined ID	Integer
maxdepth	Soil layer thickness in meter	Real
ksat	Hydraulic conductivity (cm h^{-1})	Real
theta_fc	Soil moisture at field capacity (-)	Real
theta_wp	Soil moisture at wilting point (-)	Real
theta_r	Residual soil moisture (-)	Real
theta_sat	Soil moisture at saturation (-)	Real
txtr_code	USDA texture class code (numeric) 1:sand, 2:Loamy sand, 3:sandy loam, 4:loam, 5:silt loam, 6:silt, 7:sandy clay loam, 8: clay loam, 9: silty clay loam, 10: sandy clay, 11: silty clay, 12:clay	Integer

Land use

Table 15: table from layer Uses map [idr_usemap]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the land use area	String
extid	External ID used to connect land use types	Integer
date	Date associated with the feature (leave empty for time-independent data)	Date

Table 16: table from layer Irrigation methods map [idr_irrmap]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the irrigation method area	String
extid	External ID used to connect irrigation method types	Integer
date	Date associated with the feature (leave empty for time-independent data)	Date

Table 17: table from layer Crop types [idr_crop_types]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer64
name	Name of the crop	String
sowingdate_min	minimum sowing date expressed as day of the year [1-366]	Integer64
sowingdelay_max	maximum number of days when sowing can be performed	Integer64
harvestdate_max	maximum harvest date expressed as day of the year [1-366]	Integer64
harvnum_max	maximum number of harvests/cuts per the year	Integer64
cropsoverlap	minimum number of days between two subsequent crops in case of double cropping	Integer64
tsowing	minimum sowing temperature (°C)	Real
tdaybase	minimum temperature for crop growth (°C)	Real
tcutoff	maximum temperature for crop growth (°C)	Real
vern	response to vernalisation [1=Yes, 0=No]	Integer64
tv_min	minimum temperature for optimal vernalisation (°C)	Real
tv_max	maximum temperature for optimal vernalisation (°C)	Real
vfmin	vernalization factor at the beginning of the vernalisation process (-)	Real
vstart	number of days required for vernalisation to start	Integer64
vend	number of days required for vernalisation to end	Integer64
vslope	vernalisation curve parameter	Real
ph_r	photoperiod impact [0=Day-neutral plants, 1=Long-day plants, 2=Short-day plants]	Integer64
daylength_if	day length threshold below (above) which no accumulation of physiological time occurs for long-day (short-day) crops	Integer64
daylength_ins	day length threshold above (below) which maximum accumulation of physiological time occurs for long-day (short-day) crops	Integer64
wp	biomass water productivity [t/ha] (C4 crops = 0.30 – 0.35, C3 crops = 0.15 – 0.20, some leguminous crops < 0.15 t/ha)	Real
fsink	crop sink strength coefficient	Real
tcrit_hs	critical temperature threshold for heat stress (°C)	Real

tlim_hs	limit temperature threshold for heat stress (°C)	Real
hi	harvest index (-)	Real
kyT	water stress coefficient for the overall crop growth cycle (-)	Real
ky1	water stress coefficient for the ini stage (-)	Real
ky2	water stress coefficient for the dev stage (-)	Real
ky3	water stress coefficient for the mid stage	Real
ky4	water stress coefficient for the end stage	Real
praw	parameter to compute RAW	Real
ainterception	parameter to calculate interception	Real
cl_cn	CN class	Integer64
irrigation	irrigation [1 = Yes, 0 = No]	Integer64
gdd	Growing degree days (list of values separated by space)	String
kcb	Cultural coefficients (list of values separated by space)	String
lai	Leaf area index (list of values separated by space)	String
hc	Plant heights (list of values separated by space)	String
sr	Root depths (list of values separated by space)	String
adv_opts	Advanced options in the form: par_name1=par_value1; par_name2=par_value2; …	String

Table 18: table from layer Soil uses [idr_soiluses]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer
name	Name of the soil use	String
descr	Description of the soil use	String
croplist	Crops ids (list of values separated by space)	String

Table 19: table from layer Irrigation methods [idr_irrmet_types]

Name	Description	Data type
fid	System defined ID	Integer64
id	User defined ID	Integer64
name	Name of the crop	String

qadaq	Irrigation water depth/volume per unit area (mm)	Real
k_stress	Water stress coefficient for the activation of irrigation from water diversions	Real
k_stresswells	Water stress coefficient for the activation of irrigation from private wells	Real
min_a	Parameter of percolation model	Real
max_a	Parameter of percolation model	Real
min_b	Parameter of percolation model	Real
max_b	Parameter of percolation model	Real
losses_a	Parameter of irrigation losses model	Real
losses_b	Parameter of irrigation losses model	Real
losses_c	Parameter of irrigation losses model	Real
f_interception	Check if irrigation water is intercepted by foliage [1: True, 0: False]	Integer64
irr_time	Hours in a day, 1 to 24 (list of values separated by space)	String
irr_fraction	Irrigation distribution factors, the sum is one (list of values separated by space)	String
adv_opts	Advanced options in the form: par_name1=par_value1; par_name2=par_value2; …	String

Need help?

As most of the issues that you can meet with the use of IdrAgraTools are of interest also for other users, we encourage the use of the issue tracking system available here:

https://github.com/rita-tools/IdragraTools/issues

For more specific requests, please write to:

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