



Action E3

Model for evaluation of sustainability *“Imagine Sustainability”* User Manual

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of sustainability**
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User Manual

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30/09/2025

LIFE IPE IMAGINE

LIFE19 IPE/IT/00015

Realized by DSA3 - UNIPG

Abstract

Assessing sustainability at the territorial level requires the use of a model that allows for an integrated understanding of social, environmental, and economic issues. This model is useful for monitoring ongoing territorial dynamics and territorial planning activities in compliance with the principle of sustainability.

IMAGINE SUSTAINABILITY is a territorial sustainability assessment tool, implemented as part of the Life Imagine Project, whose objective is to conduct sustainability analyses at the territorial level, with particular reference to the Natura 2000 network.

This model should become a reference point for assessing the network's sustainability, using municipal-level data or specific indicators related to Natura 2000 sites. Assessing sustainability means continuously monitoring the progress made in Natura 2000 areas, not only in terms of biodiversity conservation, but also considering the three dimensions of sustainability—economic, social, and environmental, represented by specific indicators—in the broader context of achieving the 17 sustainability goals established by the United Nations 2030 Agenda.

Imagine Sustainability is configured as a plugin of the software QGIS. This document represents the User Manual of the plugin.

Imagine Sustainability

User Manual

Summary

1. Introduction – Model Objectives and Context
 2. Model Structure
 3. Calculation Methodology
 4. Installation of the Imagine Sustainability Plugin
 5. Types of Required Inputs
 6. How the Plugin Works
 7. Types of Obtainable Results
 8. Traceability Analysis Using Back Analysis
- Bibliography

1. Introduction – Model objectives and context

Assessing sustainability at the territorial level requires the use of a model that allows for an integrated understanding of social, environmental, and economic issues. This model is useful for monitoring ongoing territorial dynamics and territorial planning activities in compliance with the principle of sustainability.

IMAGINE SUSTAINABILITY is a territorial sustainability assessment tool, implemented as part of the Life Imagine Project, whose objective is to conduct sustainability analyses at the territorial level, with particular reference to the Natura 2000 network.

This model should serve as a reference point for assessing the network's sustainability, using municipal-level data or specific indicators related to Natura 2000 sites. Assessing sustainability means continuously monitoring the progress made in Natura 2000 areas, not only in terms of biodiversity conservation, but also considering the three dimensions of sustainability - economic, social, and environmental, represented by specific indicators - in the broader context of achieving the 17 sustainability goals established by the United Nations 2030 Agenda.

The application of the model will ensure true integration and synergy in the effects of all the actions envisaged by the IMAGINE project, from those for environmental conservation and enhancement to those of a socioeconomic nature (e.g., green professions, nature tourism, sustainable agriculture and forestry).

The model is primarily intended for public decision-makers (e.g., Regions, Municipalities). It will identify the strengths and weaknesses of the path towards sustainability and enable decision-makers to implement corrective measures. For example, applying the sustainability assessment model might reveal that a Natura 2000 site boasts excellent conservation conditions for species and habitats, but is poorly enhanced due to a lack of nature tourism initiatives. This creates an imbalance in terms of sustainability compared to the economic and social dimensions. The application of this model by a public entity allows for timely intervention by decision-makers to address this issue, for example, by allocating specific resources for the development of nature tourism in that area.

2. Model structure

The entire Imagine Sustainability process was implemented in a widely used open-source GIS (Geographic Information System) environment, called QGIS. Specifically, Imagine Sustainability uses a multi-criteria analysis model completely integrated into a GIS environment.

The complete QGIS manual and a software installation guide are available at: <https://qgis.org/it/docs/index.html>

Among the many existing features in QGIS for geographic analysis, there is the possibility of developing tools for customizing the software through plugins. A plugin is a non-standalone program that interacts with another program to expand or extend its original functionality, allowing the use of new features not present in the main software. Imagine Sustainability is essentially a plugin of QGIS, written in Python, which uses the libraries (set of functions or data structures) provided by QGIS itself to perform the processing requested by the user. In addition to performing the calculations required by the evaluation algorithm, input and output data can be managed like any other geographic data, and the user is free to perform further geostatistical analyses, geoprocessing, or reporting. The plugin processes data in vector format.

The model's basic structure is based on a common set of indicators, capable of representing the dimensions of sustainability, considering economic, social, and environmental variables. The aim is to enable a comparative synthesis, in terms of sustainability, between different territorial units. The unit of analysis can therefore be any territorial entity.

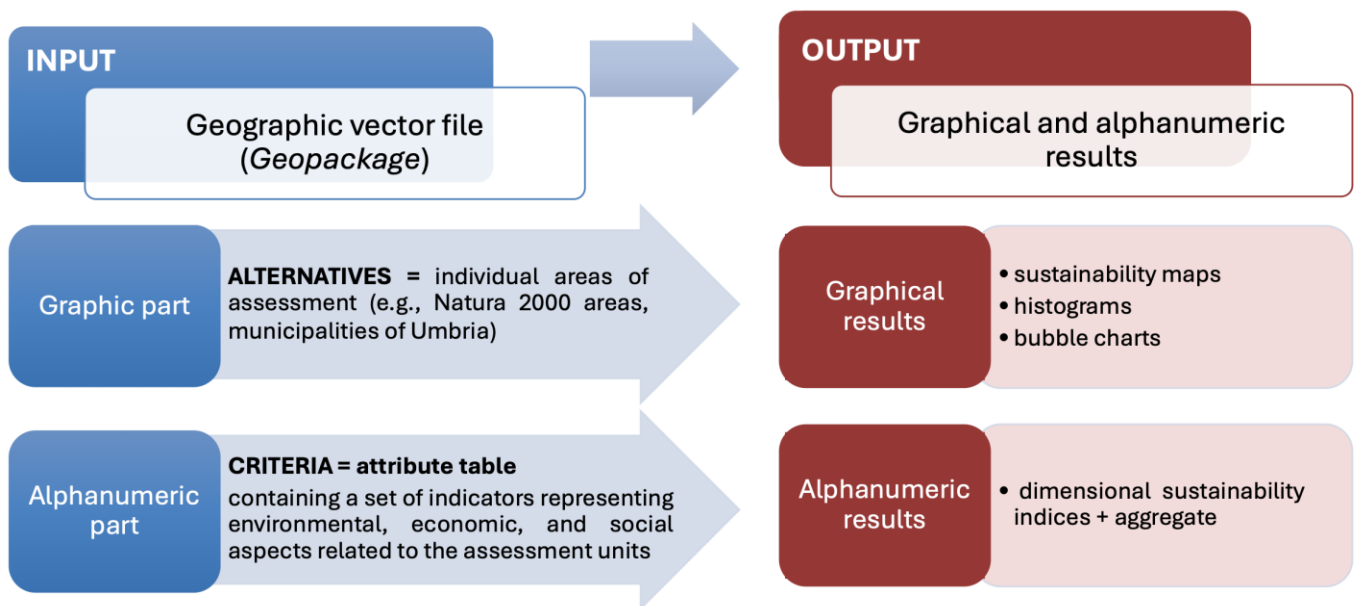
In Imagine Sustainability, the units of analysis will be the individual Natura 2000 sites in the Umbria Region, which will be compared in terms of sustainability using a previously determined set of indicators, or the municipalities of Umbria, divided based on the Natura 2000 area within them. This depends on the type of analysis being implemented.

The model integrates the geographic component, allowing for improved data analysis and processing. This model, therefore, features complete integration between Geographic Information Systems and Multicriteria Analysis.

Thanks to this geographic integration, the model offers a wide range of outputs. It provides both numerical outputs (i.e. synthetic sustainability indices) and graphical and cartographic outputs, represented by graphs and maps (Fig. 1).

Fig. 1 – Structure of the Model Imagine Sustainability

IMAGINE SUSTAINABILITY – Plugin in QGIS



3. Calculation methodology

Imagine Sustainability's results are derived through a multicriteria analysis model, which allows us to address complex problems by comprehensively evaluating all the variables involved, assigning each its relative importance. Multicriteria methods belong to the broader category of Decision Support Systems, within the scientific branch of Operational Research.

These methods allow us to classify, rank, or select a series of alternatives, evaluating them based on their ability to achieve the objectives represented by the indicators used in the analysis. These types of methods are particularly suitable when comparing different scenarios characterized by a multidimensional profile, in which the different dimensions are often conflicting, as in the case of a sustainability analysis, which involves economic, social, and environmental objectives. Ultimately, they help us find the best compromise solutions among the various objectives.

All decision support systems are very useful in the definition, planning, monitoring, and evaluation of public and territorial policies.

Among the numerous multi-criteria methods available in the literature, the **PROMETHEE II method** (Brans, 1982) was chosen for Imagine Sustainability. This method has the advantage of not allowing compensation between the descriptive criteria of the individual components, avoiding that very good performances in a few areas compensate for negative outcomes in the remaining ones.

To implement the PROMETHEE II method within the plugin, the pyrepo mcda library (<https://pyrepo-mcda.readthedocs.io/en/latest/>) was used.

The PROMETHEE structure is based on a pairwise comparison of the alternatives for each criterion considered, which must be maximized or minimized. The method considers the difference between the ratings of the two alternatives for each criterion: the greater this difference, the greater the preference for one alternative.

The outputs of PROMETHEE I are two "outranking flows":

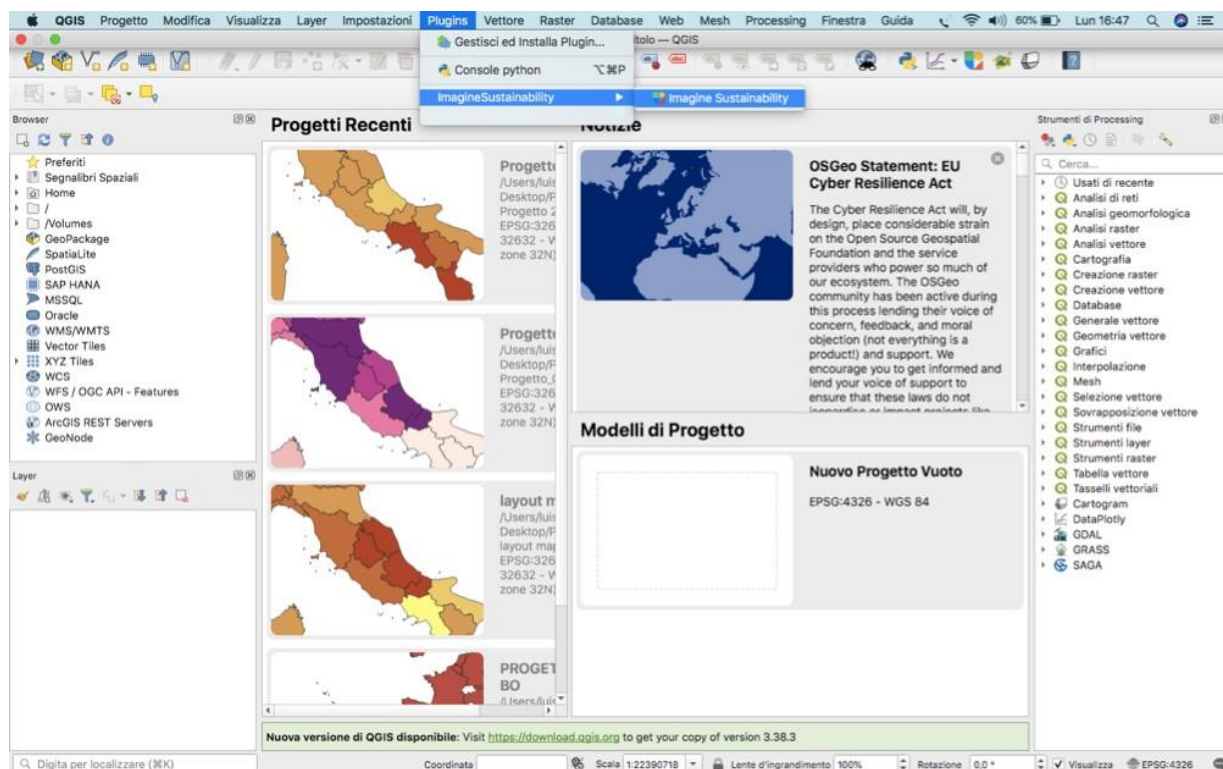
- The positive outranking flow $\Phi^+(a)$ represents the outranking power of alternative a over all others: the higher the $\Phi^+(a)$, the better the alternative.
- The negative outranking flow $\Phi^-(a)$ measures the "weakness" of alternative a and how much it is outranked by all others: the lower the $\Phi^-(a)$, the better the alternative.

PROMETHEE II, on the other hand, produces a so-called "net outranking flow" $\Phi(a)$, which is a measure of the balance between positive and negative flows. The higher the net outranking flow, the better the alternative.

4. Installation of the plugin Imagine Sustainability

- After launching QGIS, the plugin must be installed. This can be done from the menu item “Plugins / Manage and Install Plugins”, which opens a window displaying all the tools available in the repositories.
- After selecting the “All” option from the left sidebar, type “Imagine Sustainability” into the “Search” field to find the desired plugin, which can then be installed by clicking the “Install Plugin” button.
- The plugin must then be activated by opening the “Plugins / Manage and Install Plugins” window again, typing Imagine Sustainability in the search field, and checking the corresponding checkbox to enable it.
- Once the installation is complete, a new button and a new entry will appear in the “Plugins” menu (Fig. 2)

Fig. 2 – Installation of the plugin “Imagine Sustainability”.



5. Types of required inputs

The sustainability assessment procedure is based on a geographic file, specifically a **vector file in “Geopackage” format**, where the graphical component represents the study area with the individual units to be evaluated (for example, a region with its municipalities or Natura 2000 sites), while the alphanumeric component — that is, the **attribute table** — describes the environmental, economic, and social aspects of each territorial unit through a set of selected indicators. It is also possible to include a fourth dimension, related to biodiversity.

The setting of the files to be used within Imagine Sustainability can be done in various ways, and GIS-experienced users may choose the method they find most effective. Below there is the description of one possible approach, which involves integrating QGIS with a standard spreadsheet (e.g., LibreOffice Calc or similar software as Excel).

A. What You Need to Get Started

To prepare the simulation file using this approach, you will need the following two files:

- A **Geopackage file** containing the geographical units to be analyzed (e.g., the municipalities of the Umbria Region), each identified by a **unique identifier** (e.g., ID). This file is usually available and downloadable from online sources.
- A **spreadsheet** containing one column (preferably the first) with the **identifier of the geographical units** also present in the Geopackage file (e.g., ID), and the following columns with the **indicators used in the assessment**. The length of the column names must not exceed **10 characters**.

A.1. Preparing the Spreadsheet

Table 1 provides a schematic example of the structure the spreadsheet must follow:

Table 1: Example of spreadsheet structure

ID	Municip.	E_CO2	E_SOIL	E_FRAM	E_WATER	E_NAT2k
1	Acquasp.	27491,00	3,99	3,69	26,84	0,46
2	Allerona	18986,00	1,57	2,31	36,91	30,32
3	Alviano	17054,00	4,86	5,19	34,86	27,99
4	Amelia	50574,00	4,28	3,88	31,54	27,23
5	Arrone	10593,00	3,15	3,06	29,29	0,00
6	Assisi	142692,00	7,62	8,00	45,90	7,02

The first column, “ID”, contains the unique identifier of the single geographical units, which in this case are the municipalities of Umbria. The column “Municip.” contains additional information about the identification of the study areas and does not affect the calculation procedure (the user may delete it or add other columns if desired). All other columns contain the indicators, with their names listed in the first row (e.g., E_CO2, E_SOIL, E_FRAM, etc.). In this case, the indicators are prefixed with an “E” because they are all environmental indicators. This prefix is not required for processing but is useful for distinguishing between different groups of indicators.

- The indicator columns must be formatted in Calc using a numeric format (decimal) and setting the desired number of decimal places. This can be done easily via the “Format / Cells” command in Calc after selecting the cell or range of cells to format.
- From LibreOffice Calc, select “Save As”, and after choosing the DBF format (or Excel format, if using Microsoft Office), save the file containing the indicators to be imported into QGIS.

B. Loading the Two Preliminary Files into QGIS

- At this point, switch to QGIS and, using the “Layer / Data Source Manager” command, load the Geopackage file containing the geographical units to be analyzed (e.g., the polygons of the municipalities in Umbria – see Fig. 3). Still within QGIS and using the same procedure, load the spreadsheet file containing the indicators previously prepared (as described in section A.1) (see Fig. 4). In this way, both files will be loaded into QGIS.

Alternatively, you can load both files by simply dragging them from the folder where they are saved directly into the QGIS workspace.

- Make sure that both files contain a unique identifier that can be used to associate the polygon features with the indicator data for the simulation.

In the example, the unique code is stored in the “ID” field in both the spreadsheet and the Geopackage file, and refers to the identifier of each municipality. You can check this by opening the attribute table and reviewing the available fields.

Note that the identifier can be an integer, a character string, or a combination of both.

Fig. 3 - Uploading the “Umbria Municipalities” geographic file into the plugin

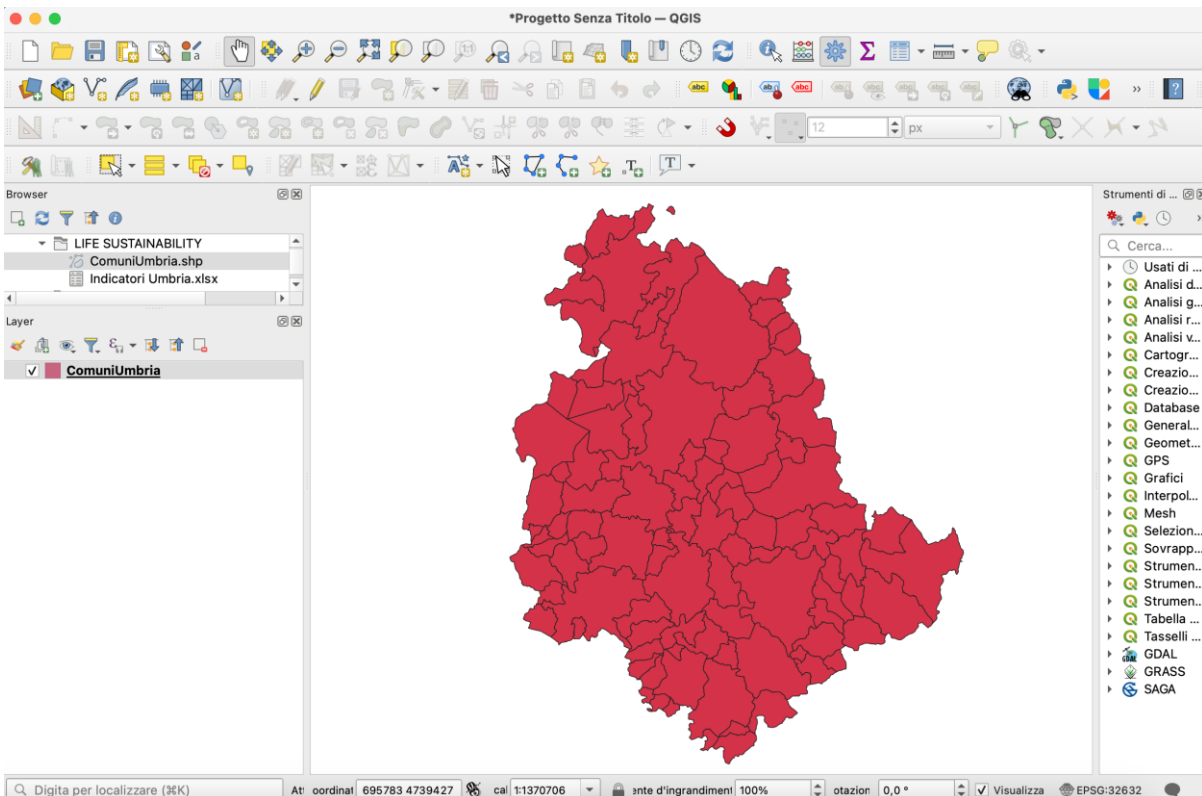
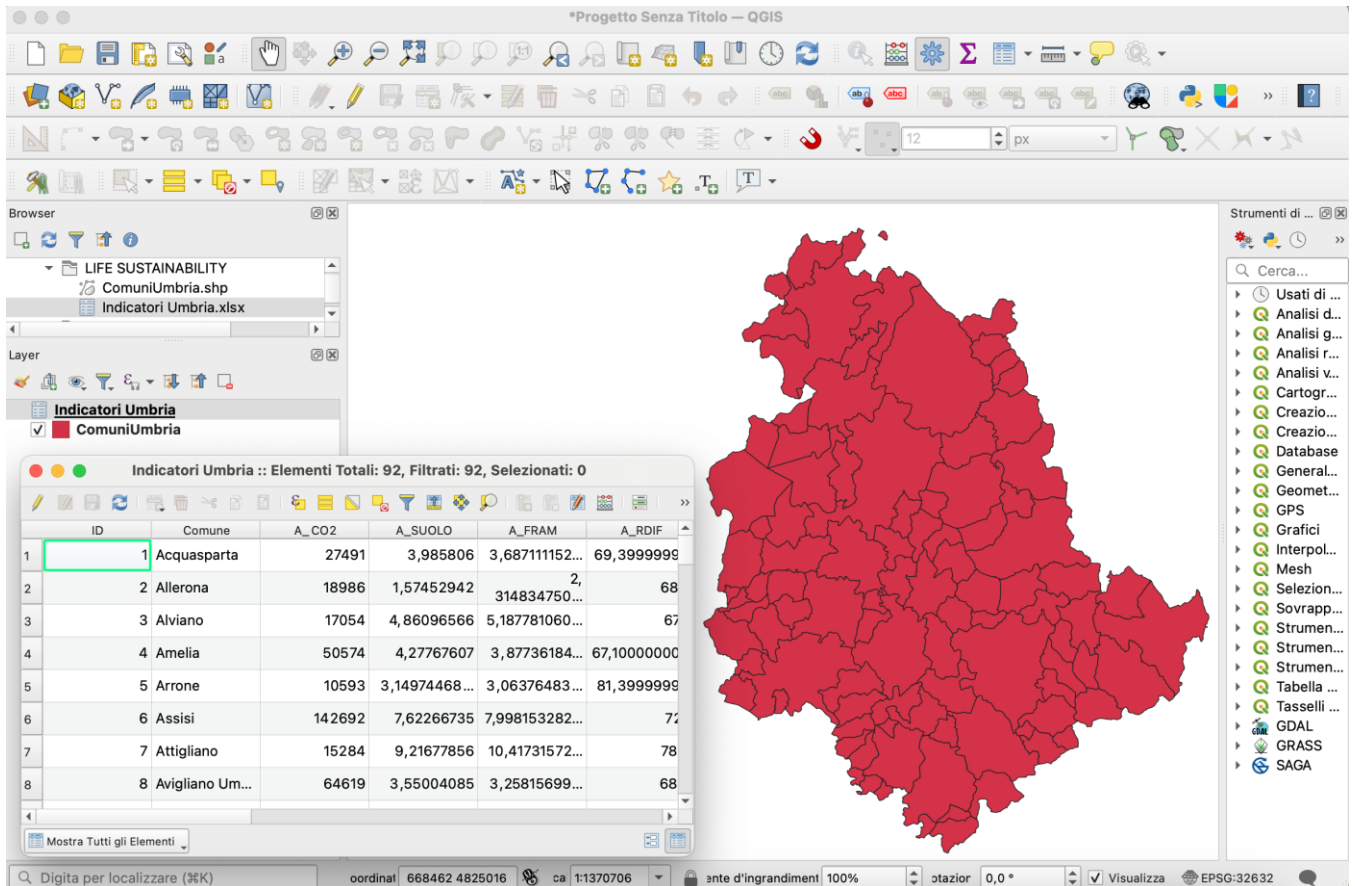


Fig. 4 - Loading the indicators file into the plugin



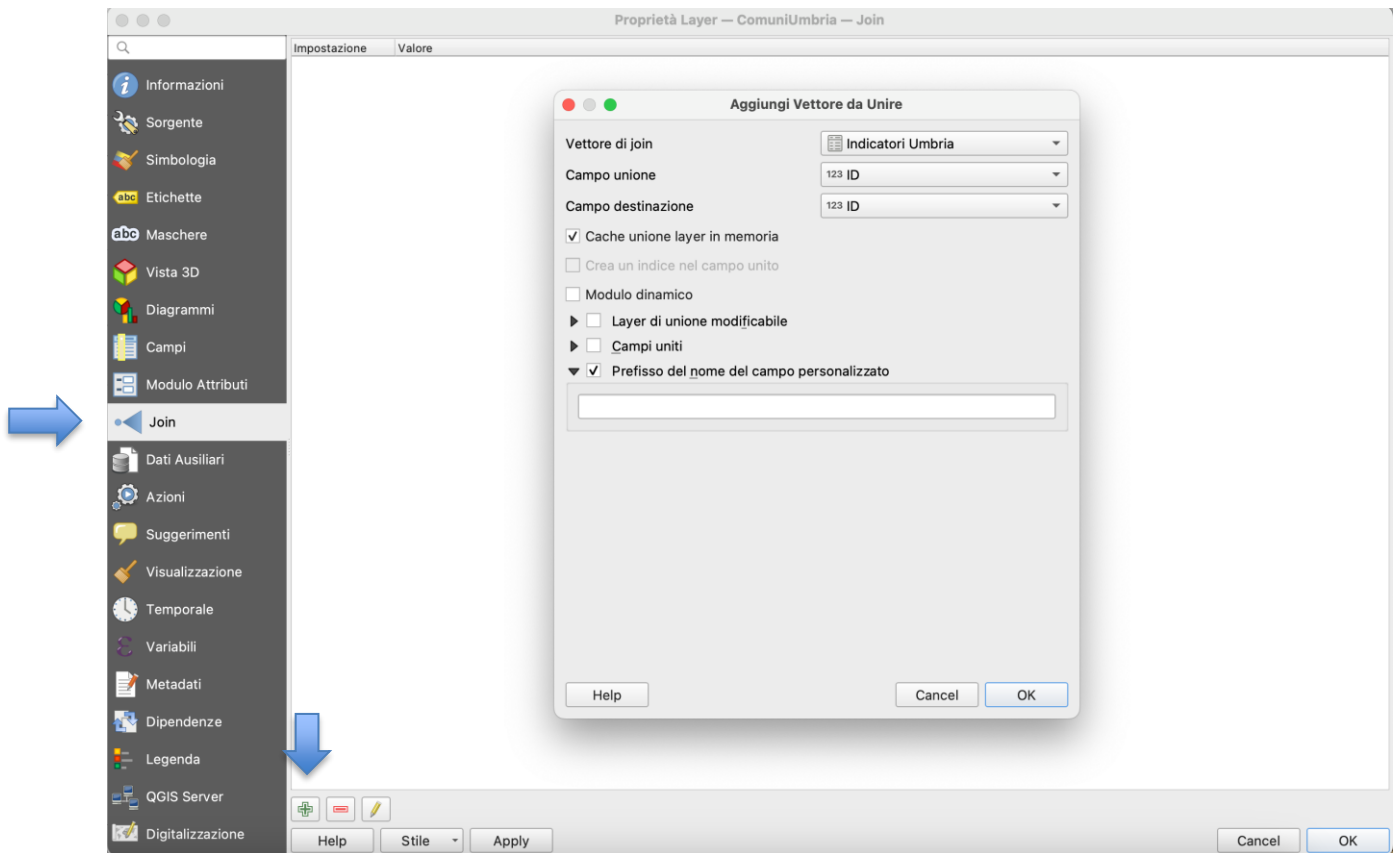
C. "JOIN" operation:

This procedure is used to link the geographic file with the indicators table.

- Select the geographic file previously loaded that corresponds to the units under study, then right-click and choose "Properties."

A window will open with several options on the left sidebar; among these, select "Join" (see Fig. 5).

Fig. 5 – Join operation



- At the bottom left, there is a button with a “+” sign (Fig. 5); click on it to open a new window where you need to specify:

1. In the “**Vettore di join**” menu, select the name of the spreadsheet containing the indicator values;
2. In the “**Campo unione**” menu, select the name of the field in the table that uniquely identifies the individual geographical units of analysis (ID);
3. In the “**Campo destinazione**” menu, select the name of the field in the Geopackage file that uniquely identifies the individual geographical units and corresponds in value to the field selected in point 2.

- Check the option “Prefisso del nome del campo personalizzato” and delete the default value in the adjacent text box, then click “OK” to complete the operation.

With this procedure, we have simply linked the geographic file with the tabular information, associating each polygon with a row in the file containing the indicator data, based on a common key shared between the geographic file and the spreadsheet.

D. Saving the “complete” file

At this point, the geographic file will have been enriched with the information previously prepared in LibreOffice Calc, but to make the link permanent and avoid altering the original files, you need to save the file with a new name by right-clicking on the file name and selecting “Export / Save Features As...”.

In the window that will open, specify the Geopackage format, the file name, and the destination folder.

The file is now ready to be processed in Imagine Sustainability.

6. How the plugin works

We are ready to run Imagine Sustainability by following these steps:

Step 1. Loading the “complete” file

Using the “Layer / Data Source Manager” button, load the Geopackage file that we previously prepared (see point 5). The file can also be loaded by simply dragging it from the folder where it is saved into QGIS.

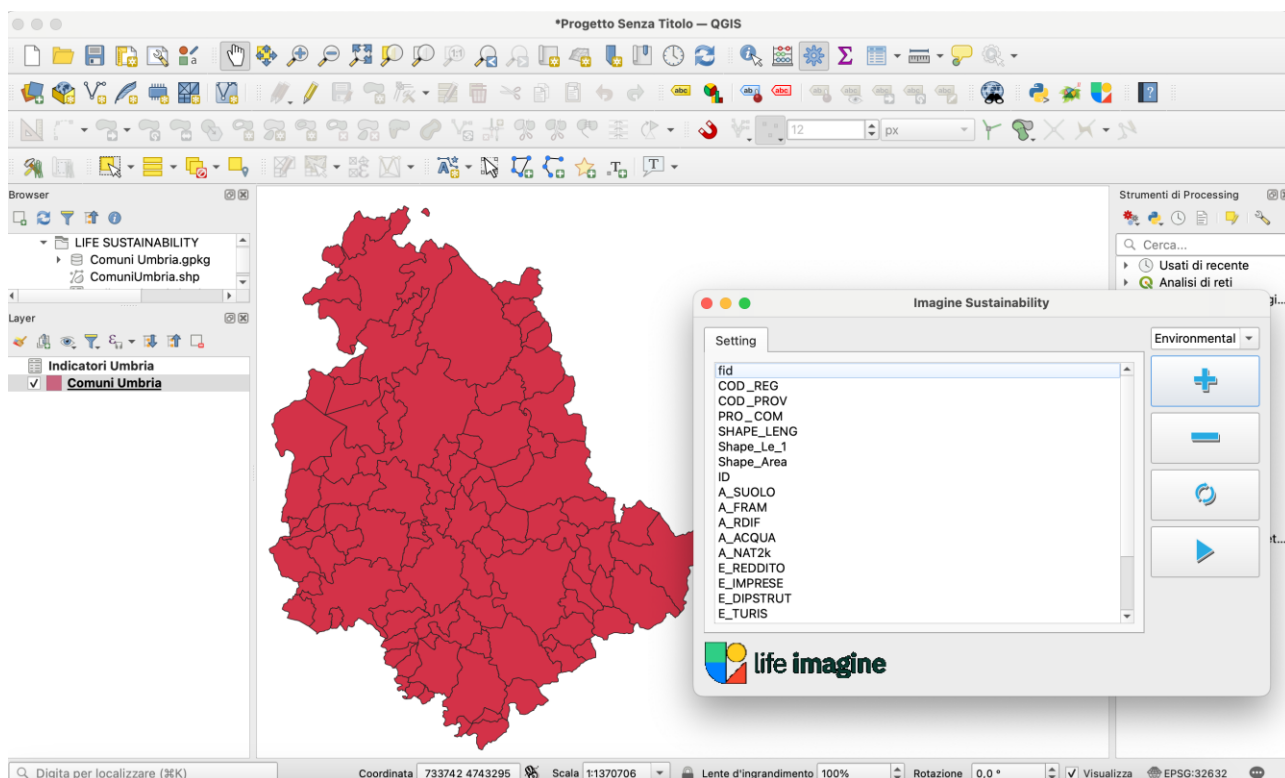
Once loaded, select the file by clicking once on its name in the active layers panel, then launch Imagine Sustainability by finding it under the Plugins menu.

Step 2. Setting phase and indicator selection

When the plugin starts, a window called “Setting” will open.

On the left side of the window, all the indicators present in the simulation file are listed, while on the right side there is a dropdown menu to select the type of indicator (Environmental, Social, Economic, Biodiversity), along with “+ Add” and “- Remove” buttons needed to add or remove individual indicators (see Fig. 6).

Fig. 6 – Settings window for inserting indicators



Starting with the environmental dimension, for example, the user can select all the environmental indicators to be used in the analysis, then choose the "Environmental" dimension from the drop-down menu on the right and click the "Add" button, thus inserting them into the corresponding section. The same process will be performed for the other dimensions (Figs. 7, 8, and 9). Given the tool's purpose, there is also the option to insert a category linked to specific biodiversity indicators (Biodiversity category). This increases the investigated dimensions to four. Furthermore, it is possible to select any of the categories and, after highlighting them, change their default name (e.g., Environmental can be shortened to ENV).

Fig. 7 - Environmental indicators entry phase

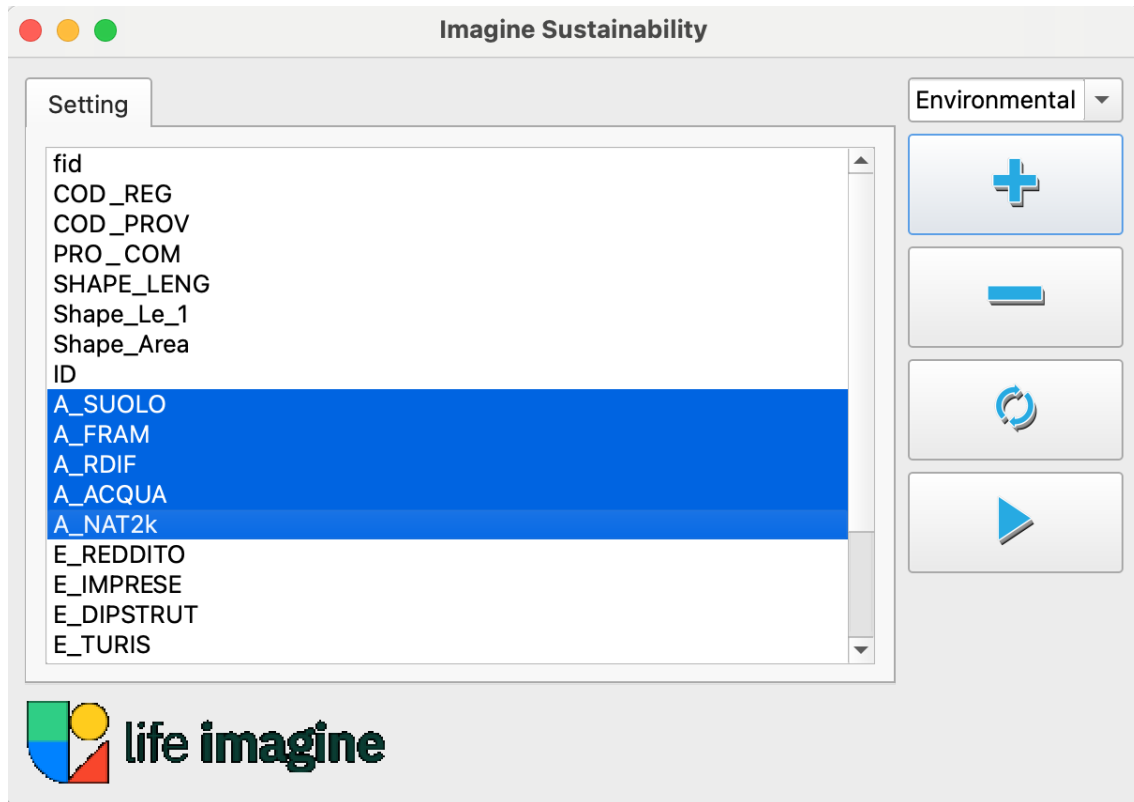


Fig. 8 - Economic indicators entry phase

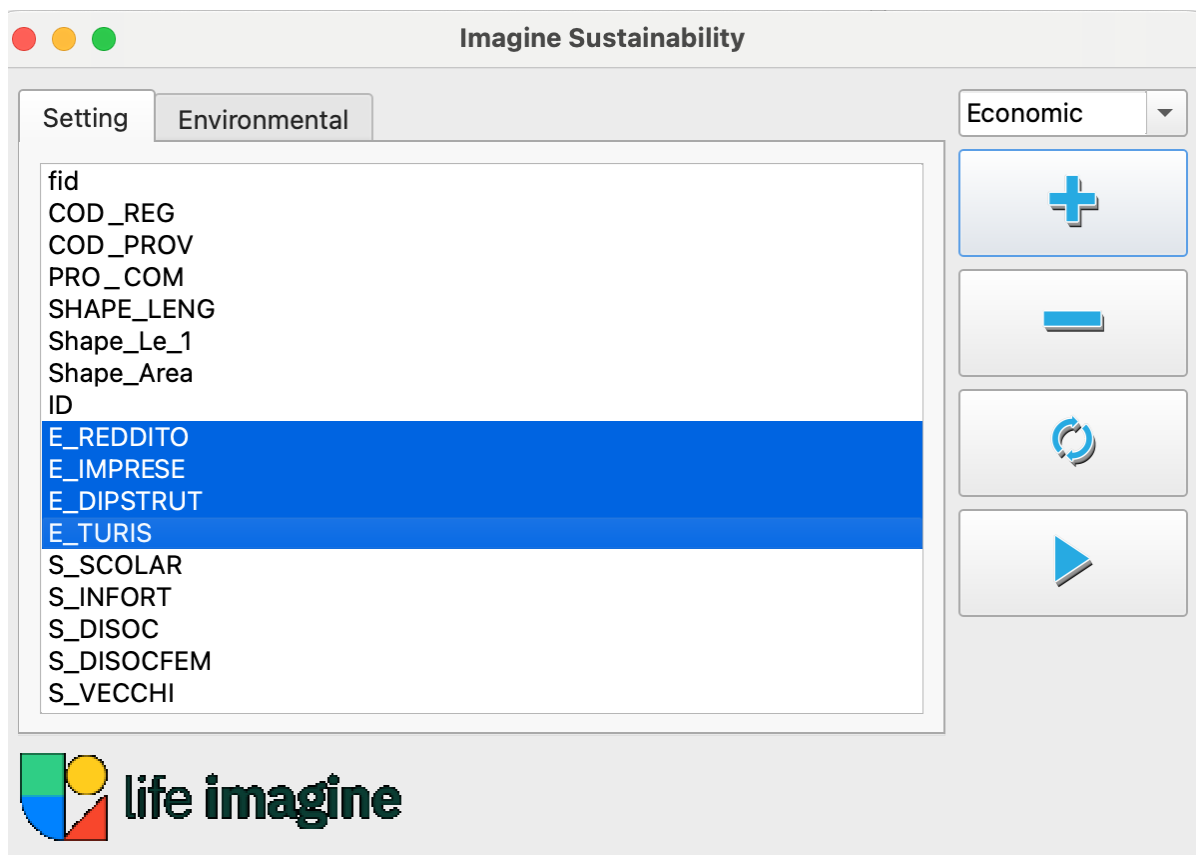
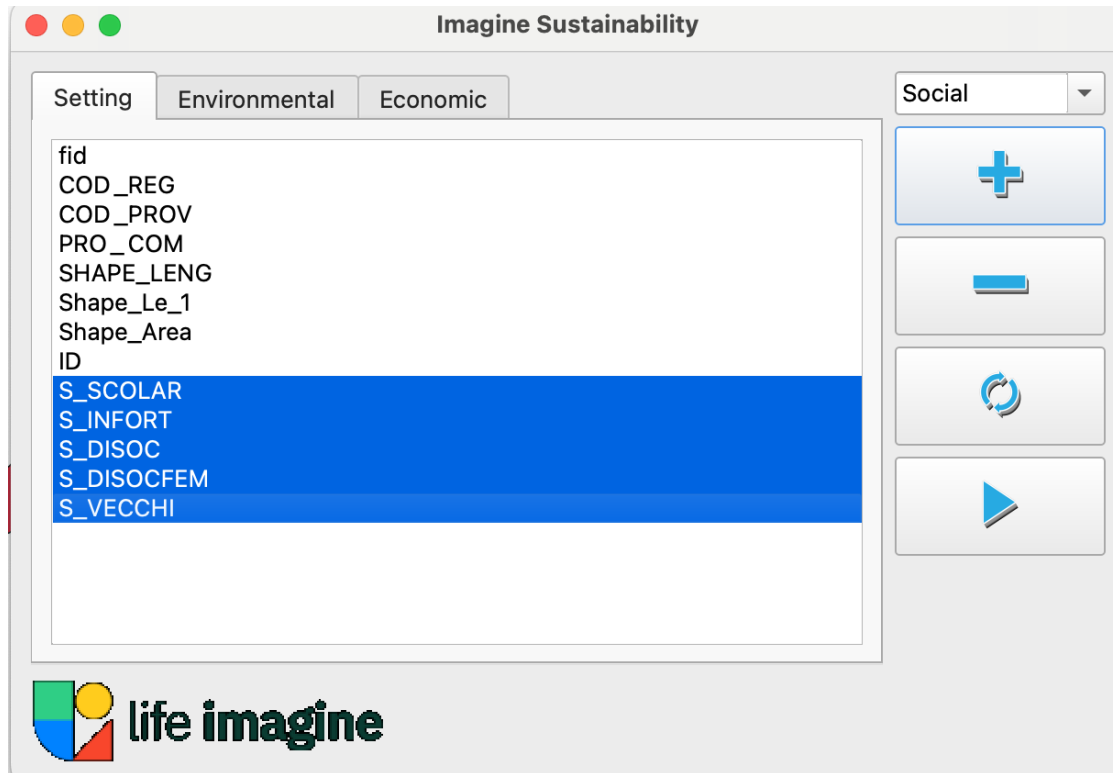
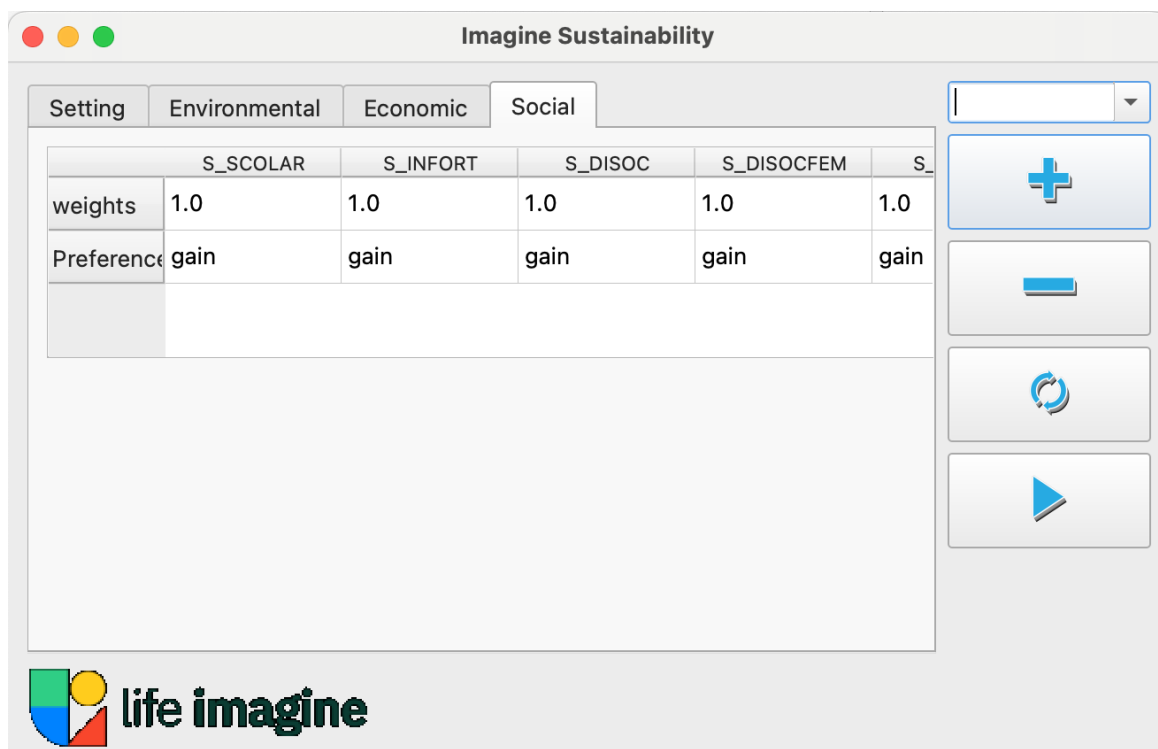


Fig. 9 – Social indicators entry phase



A table is thus constructed, with the different dimensions covered, where the relevant indicators have been inserted for each dimension (Fig. 10).

Fig. 10 - Final matrix with the three sustainability dimensions



Step 3. Setting Weights and Preferences

At this stage, it remains to define the weights (which are an integral part of the multi-criteria analysis) and the preference directions (Fig. 11).

- The “Weights” row contains the weights assigned to each criterion listed in the columns. The value of each weight can be entered directly by the user: the sum of the weights in each row must equal 1.

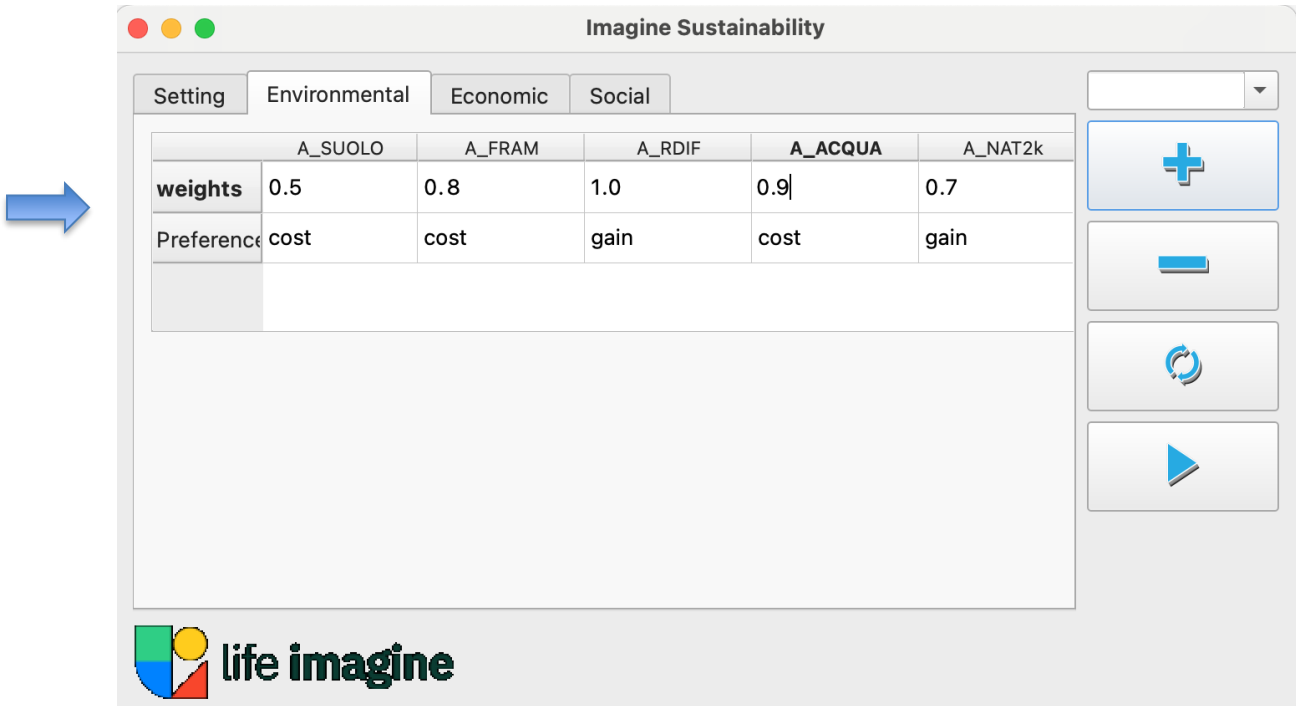
There are various methods for calculating the weights to assign to each criterion, but these are not covered in this guide.

- The “Preference” row specifies the direction of preference for each criterion in the sustainability calculation — that is, how the indicator behaves. If an increase in the numerical value of the criterion corresponds to improved sustainability, then the value should be set to “Gain”. Otherwise, it should be set to “Cost”.

Clicking on the cell with the mouse will toggle the value between “Gain” and “Cost”.

These operations — defining weights and preference directions — must be carried out for each of the analyzed dimensions.

Fig. 11 - Defining weights and preferences



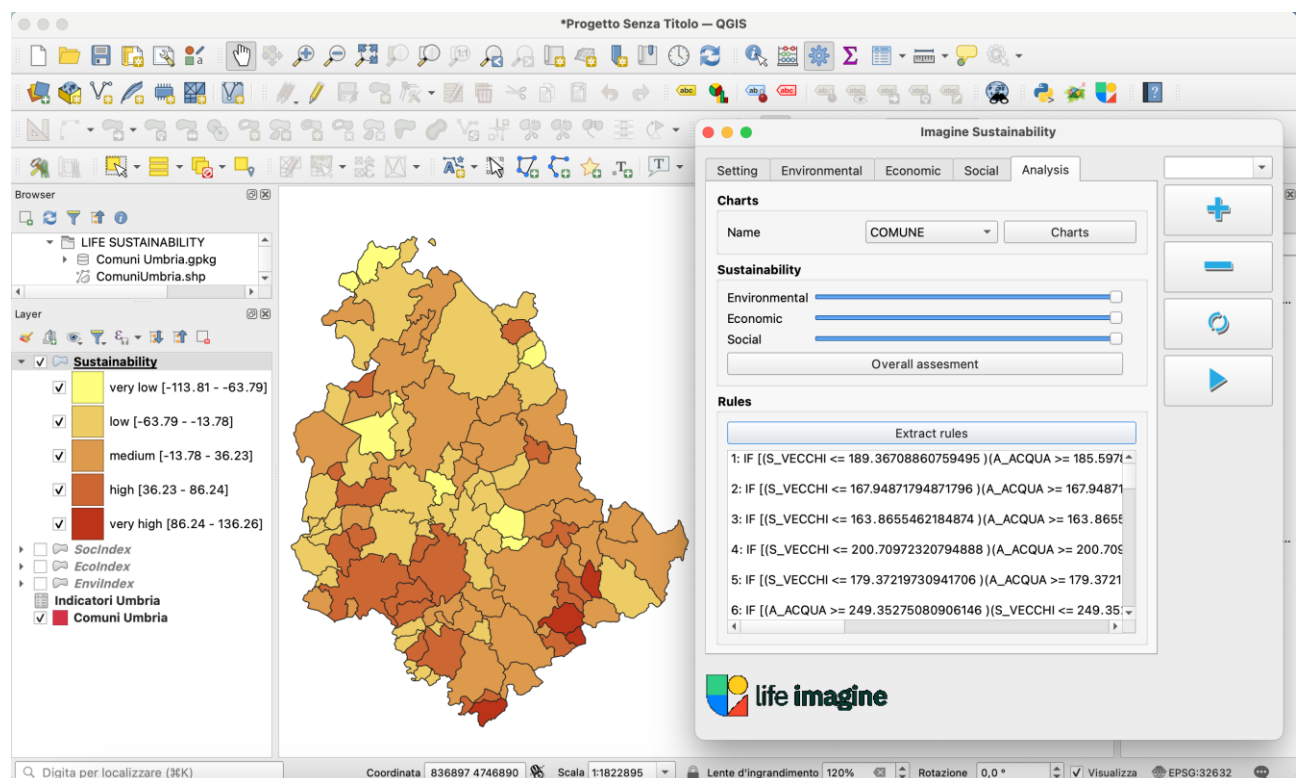
The screenshot shows the 'Imagine Sustainability' application window. The 'Setting' tab is active, displaying a table for defining weights and preferences for five criteria: A_SUOLO, A_FRAM, A_RDIF, A_ACQUA, and A_NAT2k. The 'weights' row shows values 0.5, 0.8, 1.0, 0.9, and 0.7. The 'Preference' row shows 'cost', 'cost', 'gain', 'cost', and 'gain'. A blue arrow points to the 'weights' row.

	A_SUOLO	A_FRAM	A_RDIF	A_ACQUA	A_NAT2k
weights	0.5	0.8	1.0	0.9	0.7
Preference	cost	cost	gain	cost	gain

Step 4. Processing results

- Once the operations described in step 3 are complete, click the right arrow, corresponding to the "Process" command. This process creates the indices for the three dimensions and the corresponding maps (see the next section on the type of results).
- After combining the indices for the individual dimensions according to the user's preferences using the horizontal slide bars (Fig. 12), click the "Overall Assessment" button to proceed with the overall sustainability assessment.
- At this point, a new layer called "Sustainability" will appear in the QGIS layers panel (located in the left column), along with all the sustainability maps resulting from the processing.

Fig. 12 – Global sustainability assessment through a linear combination of individual indices.



- The numerical results can be exported by right-clicking on “Sustainability”, going to “Export/Save items as/Spreadsheet format”, and then saving the file, for example, with the name “Results”, in the same folder where the initial files needed for processing were also saved.

7. Types of obtainable results

Imagine Sustainability produces both numerical outputs (synthetic sustainability indices) and graphical/cartographic outputs, represented by charts and maps.

Numerical Sustainability Indices

When considering the three classical dimensions of sustainability, three types of numerical indices are calculated for each territorial unit analyzed, in line with the strong sustainability principle, which keeps the three dimensions separate:

- Environmental Sustainability Index (ENVINDEX)
- Economic Sustainability Index (ECOINDEX)
- Social Sustainability Index (SOCINDEX)

Additionally, a fourth index can be calculated, representing overall sustainability (SUSTINDEX), obtained through a weighted sum of the three different indices — in line with the weak sustainability principle.

Sustainability maps

By clicking on the “Sustainability” section, the sustainability maps corresponding to the three dimensions are displayed.

You can view:

- the Environmental Sustainability Map (ENVINDEX MAP)
- the Economic Sustainability Map (ECOINDEX MAP)
- the Social Sustainability Map (SOCINDEX MAP)

The fourth map, representing the Global Sustainability Index (SUSTINDEX MAP), is the result of the weighted sum mentioned above.

The map colors range from red (highest sustainability value) to yellow (lowest sustainability value), and alongside a qualitative assessment, the range to which a

given color refers is also represented. This representation can be easily modified and customized by the user with the common tools available in QGIS, and the maps can also be exported.

Charts

The “**Charts**” button in the plugin interface provides a graphical representation of the analysis results.

Three different types of charts can be displayed: the histogram (Fig. 13), the bar chart (Fig. 14), and the bubble chart (Fig. 15).

HISTOGRAM: In this chart, the three sustainability dimensions are displayed **side by side** for each unit of analysis.

There is no compensation between dimensions (in line with the principle of strong sustainability).

Each bar is dimensionless and has a value between 0 and 1. The higher the bar, the better the performance of the corresponding dimension. This chart allows you to see how well each individual dimension performs for each territorial unit analyzed.

BAR CHART: in contrast to the histogram, this chart sums the three dimensions together for each unit of analysis.

This allows for a final ranking of overall sustainability among all the territorial units (in line with the principle of weak sustainability).

The sum of the individual indices ranges from 0 to 3

BUBBLE CHART: this chart is highly effective for visualization, as it allows you to view all three sustainability dimensions in a single graph. The x-axis represents the economic dimension. The y-axis represents the social dimension. The colour of the bubbles (from red to green) represents the environmental dimension

The bubble chart is generated only when using the three basic dimensions of sustainability. If the biodiversity dimension is also included, the bubble chart is not produced.

Fig. 13 – Example of histogram

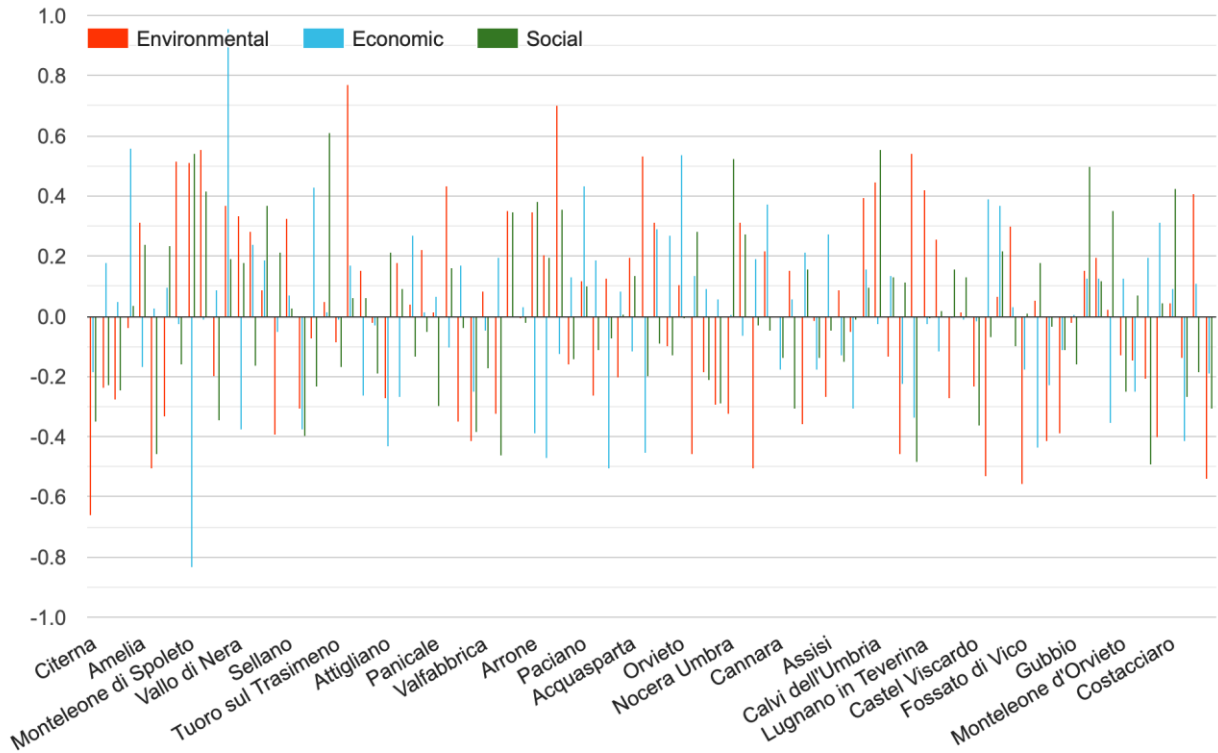


Fig. 14 – Example of bar chart

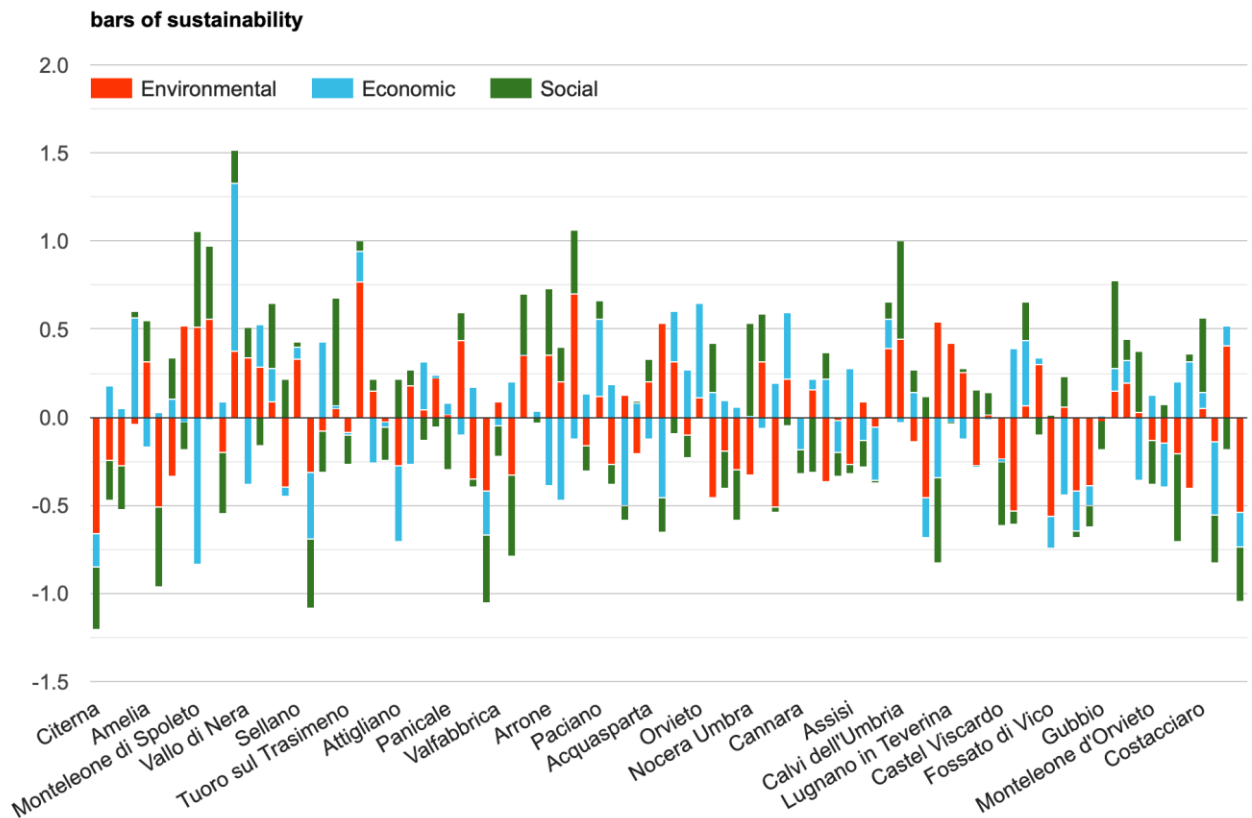
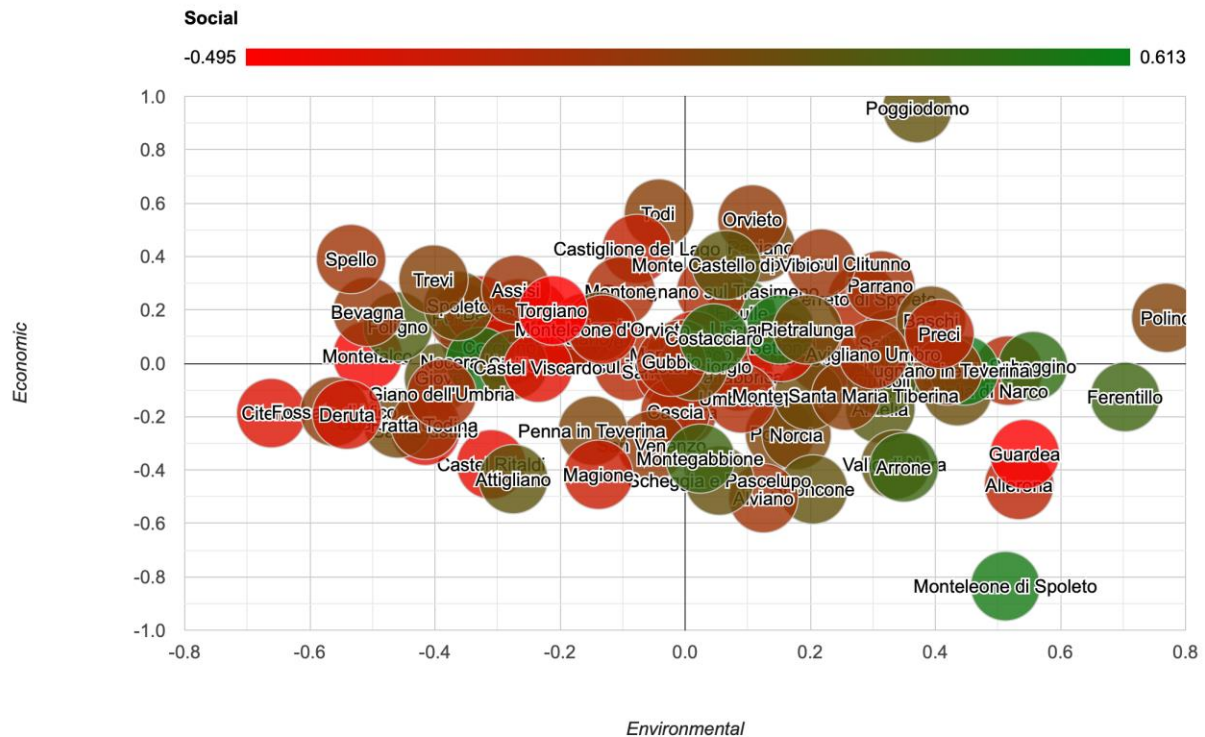


Fig. 15 – Example of bubble chart



8. Traceability Analysis using Back Analysis

The traceability analysis of results, available within Imagine Sustainability, is extremely useful and represents one of the model's key strengths.

Thanks to the application of the Dominance-Based Rough Set Approach (Greco et al., 2001), a multi-criteria method, the user is able to analyze each individual step leading to the final result, identifying which indicators and dimensions have the greatest impact on the outcomes (Back Analysis). This makes the model a transparent and easily interpretable decision-making tool.

In particular, the system generates so-called decision rules that describe the obtained results.

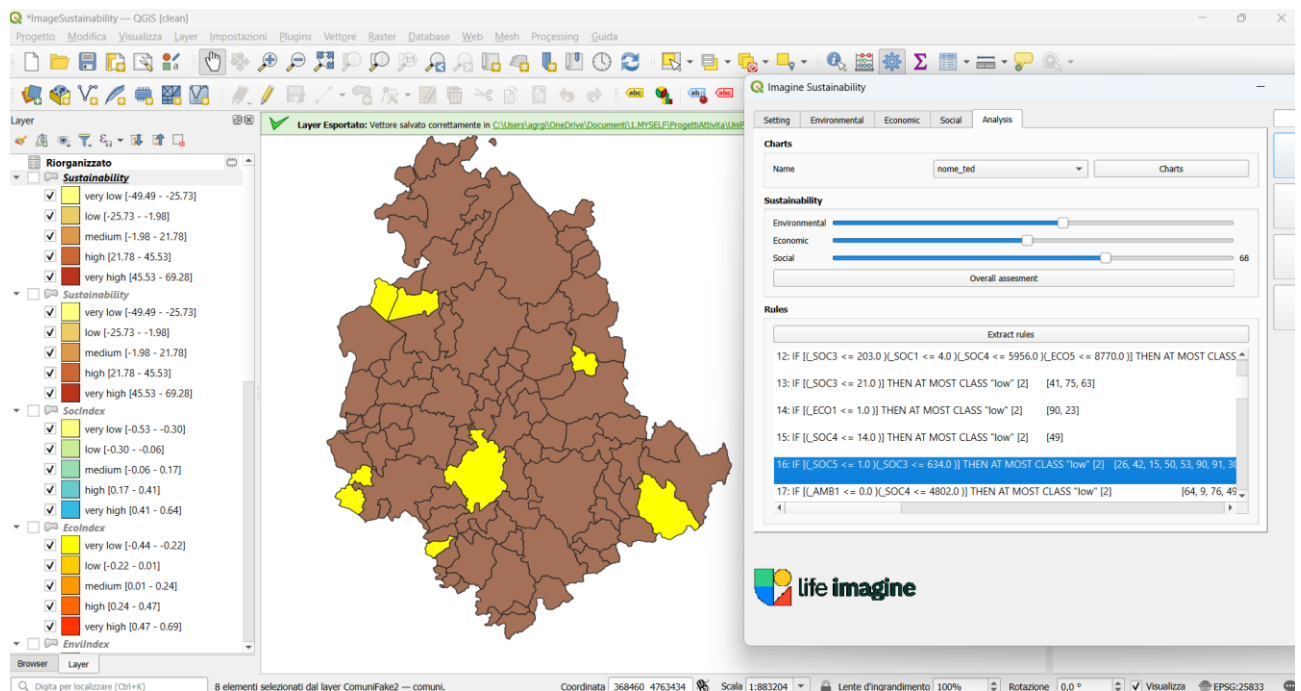
Decision rules can be defined as logical statements that are easy to understand, since they follow the "If ... then ..." structure.

Each rule includes the conditions that define it, the resulting decision class assignment, and the cases that support the rule.

The plugin window contains a button called **"Extract Rules"** (Fig. 11), which generates the decision rules based on the classification previously provided by the PROMETHEE algorithm. These rules are displayed in the "Rules" section, and by clicking on each one, the user "lights up" the geographical units where that rule is verified (Fig. 16). In other words, it is possible to visualize the individual decision rule extracted from the indicator database used in the analysis in a geographical context, showing the examples that support that rule.

- If a rule has a syntax such as **IF A >= X THEN AT LEAST i-th**, we can read it as: "If criterion A has a value greater than or equal to X, then the class to which it belongs will be at least the i-th class."
- If the extracted rule has a syntax of the type **IF A >= X THEN AT MOST i-th**, it can be read as: "If the criterion A has a value greater than or equal to X, then the class to which it belongs will be at most the i-th class".

Fig. 16 - Visualization in a geographical environment of the decision rules generated by the processing.



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