Politecnico di Torino

R3C Responsible Risk Resilience Centre

R3C-GeoResilience

Mapping Territorial Vulnerabilities

Supporting Decision Making

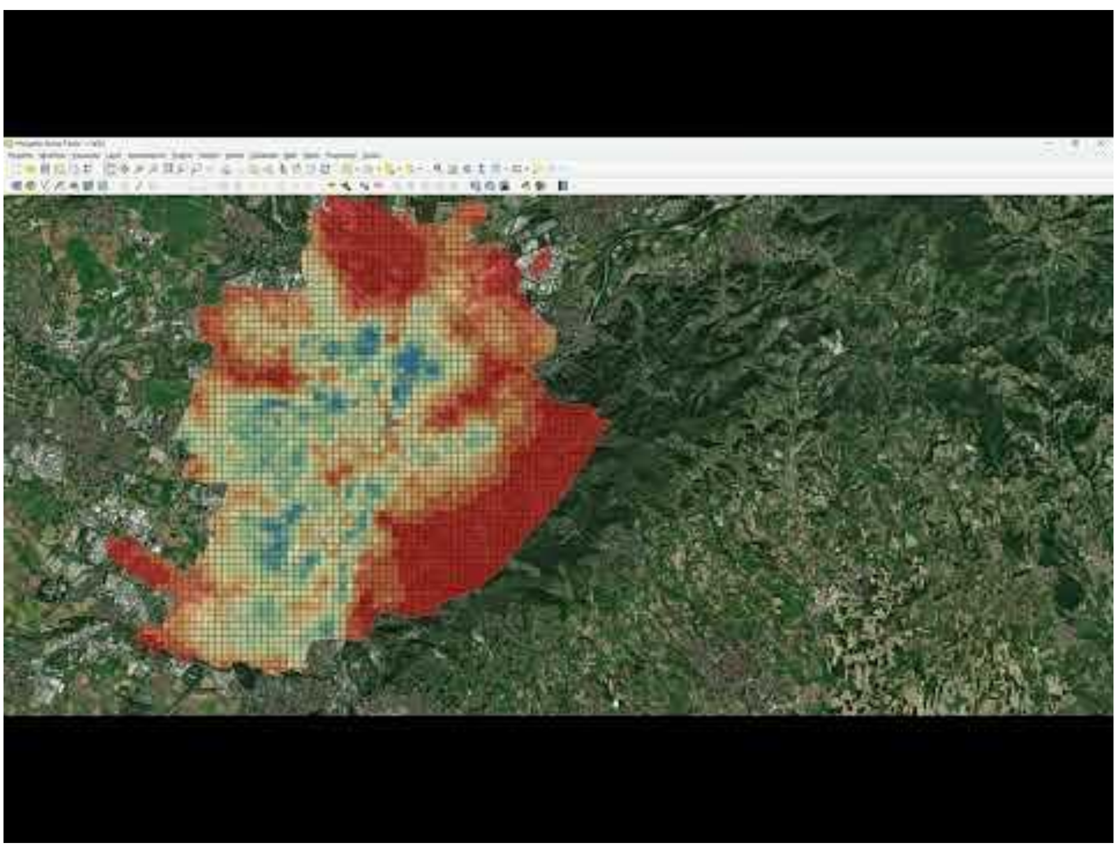
R3C-GeoResilience | Aims, Mission and Vision

Introduction

The R3C-GeoResilience is an open-source tool designed to assess territorial vulnerability through a comprehensive multi-risk analysis. Developed over the past years, **it supports local decision-makers and administrations in building resilience in their regions.** Now available for download, the tool is user-friendly and accessible to a broad range of users.

The R3C-GeoResilience offers both a simplified and advanced version, catering to different levels of expertise. The user-friendly version enables researchers, policymakers, and practitioners to visualise territorial vulnerabilities from a standardised, non-weighted perspective. For more advanced users, the tool allows for custom weighting of indicators, providing a deeper, more tailored analysis of specific territorial challenges.

The main contribution of this tool is its ability to deliver a comprehensive assessment of the various vulnerability components within a territorial system. This not only raises awareness of vulnerabilities but also **enhances the decision-making process by equipping urban planners and policymakers with the knowledge needed to design adaptive policies and land-use plans.** In doing so, it helps territories prepare for uncertainties and disruptions, fostering resilience.



Aim

The primary aim of the R3C-GeoResilience is to provide a replicable and adaptable methodology for assessing and visualising the vulnerability of a territory. It facilitates:

- The spatial representation of vulnerability by integrating sensitivity, pressure, and shock indicators into a comprehensive framework.
- Decision-making support for local actors, policymakers, and stakeholders through a multi-risk analysis of territorial vulnerabilities.
- User-friendly access to both basic and advanced analyses, allowing customisation of weighted indicators based on stakeholder needs.
- Enhanced resilience strategies by offering insights into the specific vulnerabilities of different regions.

Mission

The mission of the R3C-GeoResilience is to equip territories with a scientifically grounded, GIS-based tool for assessing and visualising vulnerabilities in a way that informs resilience-building measures. By democratising access to advanced territorial analysis, the R3C-GeoResilience supports:

- The identification and quantification of vulnerabilities across different spatial scales.
- The facilitation of participatory and data-driven decision-making processes.
- The promotion of sustainable and resilient territorial development through clear, actionable insights for policymakers, researchers, and practitioners.

Vision

The vision of R3C-GeoResilience is to establish a standard for multi-risk vulnerability assessment and territorial resilience planning. The dashboard envisions:

- Widespread use in various regions and contexts, empowering communities to proactively address and mitigate systemic risks.
- Continuous development and expansion of its features to incorporate new challenges like climate change, evolving stressors, and emerging hazards.
- Serving as a bridge between complex scientific methodologies and practical decision-making, ensuring that every territory has the tools to thrive in the face of adversity.

R3C-GeoResilience | Methodology

R3C-GeoResilience methodology for assessing territorial vulnerabilities uses a **place-based approach**

R3C-GeoResilience methodology is at the same time **applicable to other contexts**

R3C-GeoResilience proposes a tool to measure local vulnerability using a **multi-risk approach**

R3C-GeoResilience methodology integrates multiple indicators clustered into three factors defined as **sensitivities, pressures, and shocks**

Resilience is the key to coping with the ongoing global challenges

Measuring territorial vulnerabilities helps enhance resilience by identifying areas of weakness, enabling targeted interventions and informing decision-making for adaptation and mitigation strategies

R3C introduces a methodology for measuring vulnerabilities considering environmental, social and economic factors and from a multi-risk perspective

The R3C-GeoResilience open-source platform makes the methodology applicable to other territorial contexts

R3C-GeoResilience | Download

1. Access our article on the link below to understand the R3C-GeoResilience Methodology.

2. Download the R3C-GeoResilience QGIS Plugin using the link below:

- The zip file also includes the data for the city of Turin.

3. Download the R3C-GeoResilience manual.

6. Input the data in the R3C-GeoResilience plugin:

- Using the Turin data available with the R3C-GeoResilience QGIS Plugin.

- Creating an analysis of a different geographical area and context, therefore calculating the indicators referent to your area. All the steps are further explained in this manual.

7. Visualize interactively the territorial vulnerability maps.

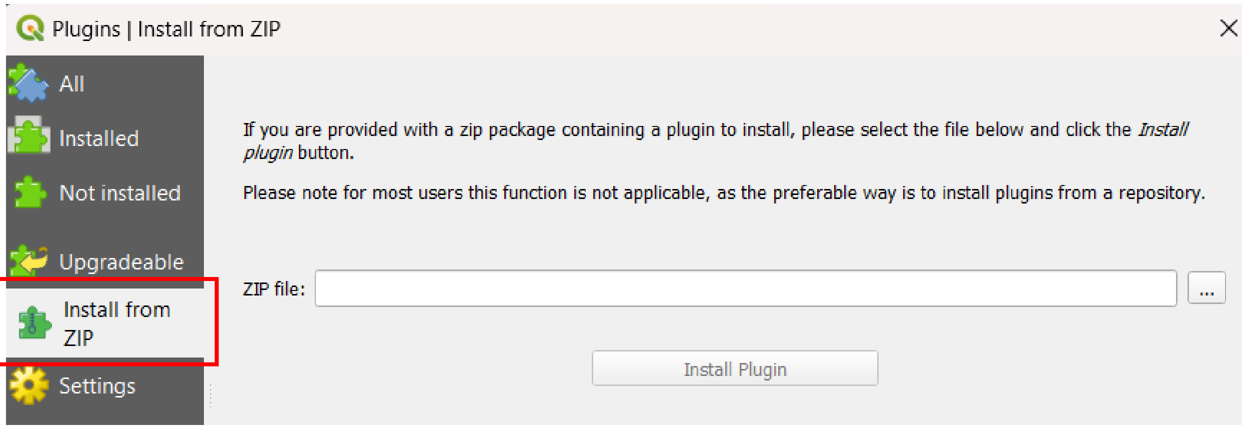
DOWNLOAD | ARTICLE

DOWNLOAD | R3C-GeoResilience

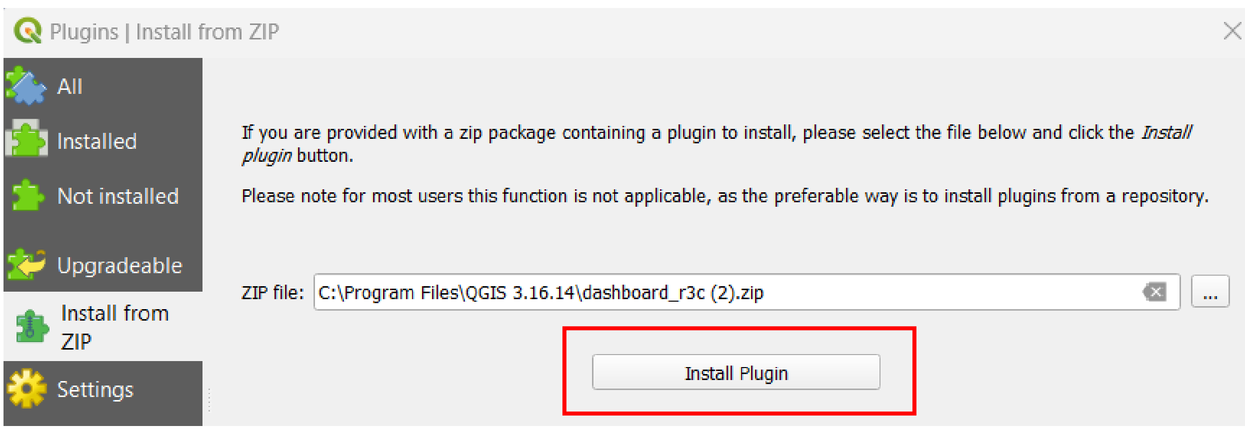
DOWNLOAD | QGIS

R3C-GeoResilience | Installing the Plugin

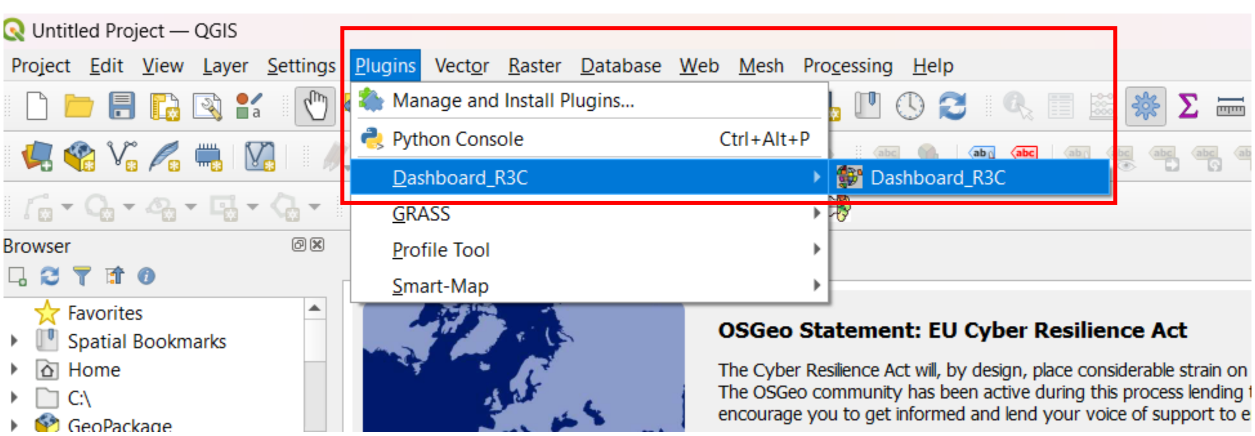
➢ Download Zip File > Access QGIS > Select window Plugins > Install from ZIP



➢ Select the ZIP file that you download "R3C-GeoResilience" > Install Plugin



➢ Restart your computer, and you're all set! The R3C Dashboard should appear on your Plugins tab



R3C-GeoResilience | Preparing QGIS Data

If you want to apply the methodology in another geographical context, it is necessary first to create a shapefile that includes all the information regarding every single indicator that you aim to use in your context. These indicators must refer to sensitivities, pressures, and shocks. A brief explanation of how to create your shapefile is provided below in different steps:

1. Interpolation

The first step is creating raster files of each indicator through interpolation techniques. Different QGIS tools can be used based on the nature of the data (e.g. point density, line density, etc.).

Click here for a tip on how to use this tool on QGIS > INTERPOLATION

2. Overlay of indicators

Convert all raster files to points and make a spatial join of all point layers.

Click here for a tip on how to use this tool on QGIS > RASTER TO POINT
Click here for a tip on how to use this tool on QGIS > SPATIAL JOINT

3. Create a fishnet grid

Use a fishnet function to create a grid of 200m x 200m.

Click here for a tip on how to use this tool on QGIS > FISHNET

4. Point to fishnet

Insert the value of the point layer, which includes all indicators, into the layer Fishnet using spatial join between the two layers.

5. Normalize the indicators

All the indicators must be normalised, so the attribute table of the Fishnet will be exported to Excel, normalised, inserted again in QGIS and joined to the grid.

The normalisation formula is:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}}$$

- X': normalized value
- X: original value
- X_{min}: minimum value in the dataset
- X_{max}: maximum value in the dataset

6. Finalising

After realising all the steps above, you should have two shapefiles to be inserted on the R3C-GeoResilience PlugIn:

1. Shapefile containing all the layers of indicators
2. Shapefile border of the territory you are analysing

R3C-GeoResilience | Preparing Excel Matrix

If you want to apply the methodology in another geographical context, it is necessary to create an Excel matrix that includes all the information regarding every single indicator that you aim to use in your context. These indicators must refer to sensitivities, pressures, and shocks. A brief explanation of how to create your Excel matrix is provided below in different steps:

1. Filling in the Excel Matrix

Sensitivity						Pressure		Shock	
Component_A	**Alias_A**	**Component_B**	**Alias_B**	**Component_C**	**Alias_C**	**Pressure**	**Alias_P**	**Shocks**	**Alias_S**
A1	IMP	**B1**	RIA	**C1**	PD	**P1**	SC	**S1**	FL
A2	TREES	**B2**	CHS	**C2**	EC	**P2**	DE	**S2**	SR
A3	GREEN	**B3**	BA	**C3**	IC	**P3**		**S3**	LS
A4		**B4**	CLA	**C4**	SAS	**P4**		**S4**	UHI
A5		**B5**	ESA	**C5**		**P5**		**S5**	
A6		**B6**		**C6**		**P6**		**S6**	
A7		**B7**		**C7**		**P7**		**S7**	
A8		**B8**		**C8**		**P8**		**S8**	
A9		**B9**		**C9**		**P9**		**S9**	

The columns in the SHP in the QGIS file must be named with the names shown in grey, which cannot be changed (so A1, C1, P1, S1...)

To indicate that there is no value: leave the Alias blank

To indicate the data: provide a value to the corresponding Alias

- **Important:** Please do not modify the Excel file; simply fill it in with your data. There must be a correspondence between the contents of this Table, the Correlation Matrix and the input data grid on the SHP in QGIS, otherwise, the Plugin will identify irregularities

2. Create another file including abbreviation and description of indicators

Code	Abbreviation	Indicator	Description
A1	IMP	Impermeability	impermeable area/total area of the grid
A2	TREES	Availability of planted trees	number of total planted trees / total area of the grid
A3	GREEN	Availability of Green spaces	public green spaces area / total area of the grid
B1	RIA	Road infrastructure availability	(total lengths of road infrastructure * road class) / total area of the gird
B2	CHS	Cultural heritage sites	number of cultural sites / total area of the grid
B3	BA	building abandonment	number of abandoned buildings / total number of buildings
B4	CLA	Cycling lanes availability	total length of cycling lines / total area of the grid
B5	ESA	educational services availability	number of schools / inhabitants
C1	PD	Population density	residents population in each census section / area of the census section
C2	EC	Elderly component	residents population in each census section aged > 65 years / total population of the census section
C3	IC	Immigrant component	immigrants population in each census section / total population of the census section
C4	SAS	Social assistance servises	number of social assistance centres in each zone/ total are of the zone
P1	SC	Soil consumption	soil consumed / total area of the grid
P2	DE	depopulation	total pop 2007 - total pop 2023 / area of the grid
S1	FL	Floods	places with risk of occurrence of floods / area of the grid
S2	SR	Surface run-off	places with risk of Surface run-off according to the past record / total area of the grid
S3	LS	Lands slides	places at risk of hillside activities / total area of the grid
S4	UHI	Urban Heat Island (UHI)	level of exposure to the risk of UHI /total area of the grid

3. Choose the weighting of indicators that is better for your analysis:

Option 1: "User Friendly"

All indicators weight at **1**

To have a general analysis of the territory

Option 2: "Decision Making"

All indicators with a **specific** weight

To have a technical analysis of the territory

- **Option 1:** All weight at **1**

	P1	P2	P3	P4	P5	P6	P7	P8	P9	S1	S2	S3	S4	S5	S6	S7	S8	S9
A1	1.00	1.00								1.00	1.00	1.00	1.00					
A2	1.00	1.00								1.00	1.00	1.00	1.00					
A3	1.00	1.00								1.00	1.00	1.00	1.00					
A4																		
A5																		
A6																		
A7																		
A8																		
A9																		
B1	1.00	1.00								1.00	1.00	1.00	1.00					
B2	1.00	1.00								1.00	1.00	1.00	1.00					
B3	1.00	1.00								1.00	1.00	1.00	1.00					
B4	1.00	1.00								1.00	1.00	1.00	1.00					
B5	1.00	1.00								1.00	1.00	1.00	1.00					
B6																		
B7																		
B8																		
B9																		
C1	1.00	1.00								1.00	1.00	1.00	1.00					
C2	1.00	1.00								1.00	1.00	1.00	1.00					
C3	1.00	1.00								1.00	1.00	1.00	1.00					
C4	1.00	1.00								1.00	1.00	1.00	1.00					
C5																		
C6																		
C7																		
C8																		
C9																		

❖ **Option 2: specific weight**

1. **Fill the Matrix (Excel file) with Sensitivity, Pressure, and Shock Indicators**
    - Prepare a matrix where each **row** represents a Sensitivity indicator, and each **column** represents a Pressure or Shock indicator.
    - This matrix will be used to analyse how Sensitivity indicators relate to both Pressures and Shocks.
2. **Use a Participatory Methodology**
    - Involve a team of experts to participate in filling out the matrix.
    - Each expert independently evaluates the relationship between the sensitivity and pressure/shock indicators.
3. **Rate the Relationships Using a Likert Scale**
    - For each cell in the matrix (where a sensitivity indicator intersects with a pressure or shock indicator), the researchers will assess the relationship's intensity based on the following ordinal Likert scale:
        - **0**: No relationship
        - **1**: Weak relationship
        - **2**: Strong relationship
        - **3**: Very close relationship
4. **Calculate the Average Score for Each Indicator Pair**
    - After collecting all the experts' ratings, compute each matrix cell's average score.
    - This average score reflects the consensus on the strength of the relationship between a sensitivity indicator and a pressure or shock indicator.
5. **Normalize the Results**
    - Once the averages are calculated, **normalise** these values. Normalisation ensures that the values are on a standardised scale, typically between 0 and 1.
    - A normalised value of **0** indicates no relationship, while a value closer to **1** indicates a stronger relationship.
6. **Visualize the Matrix**
    - The normalised values are presented interactively on the matrix.
    - Each cell in the matrix is **coloured** based on the strength of the relationship, using a **semaphore-style colouring system**:
        - **Green**: Low relationship (values closer to 0)
        - **Yellow**: Medium relationship
        - **Red**: High relationship (values closer to 1)
7. **Prioritize Based on Relationship Strength**
    - The coloured matrix allows for easy visual prioritisation of relationships. Indicators with stronger relationships are given higher priority, i.e., those in red cells.
8. **Your Matrix is ready to be used on the plugin**

Rate: 0 to 3

	P1	P2	P3	P4	P5	P6	P7	P8	P9	S1	S2	S3	S4	S5	S6	S7	S8	S9
A1	3.00	0.00								3.00	3.00	3.00	2.00					
A2	3.00	2.00								3.00	3.00	1.00	3.00					
A3	3.00	2.00								3.00	3.00	1.00	3.00					
A4																		
A5																		
A6																		
A7																		
A8																		
A9																		
B1	2.00	2.00								2.00	2.00	2.00	1.00					
B2	1.00	1.00								3.00	3.00	1.00	2.00					
B3	1.00	3.00								1.00	1.00	0.00	1.00					
B4	1.00	2.00								1.00	1.00	1.00	3.00					
B5	0.00	3.00								1.00	1.00	1.00	1.00					
B6																		
B7																		
B8																		
B9																		
C1	3.00	3.00								3.00	3.00	3.00	2.00					
C2	0.00	2.00								3.00	3.00	3.00	3.00					
C3	0.00	1.00								2.00	2.00	2.00	2.00					
C4	0.00	3.00								3.00	3.00	3.00	2.00					
C5																		
C6																		
C7																		
C8																		
C9																		

Normalise: 0 to 1

	P1	P2	P3	P4	P5	P6	P7	P8	P9	S1	S2	S3	S4	S5	S6	S7	S8	S9
A1	1.00	0.00								1.00	1.00	1.00	0.67					
A2	1.00	0.67								1.00	1.00	0.33	1.00					
A3	1.00	0.67								1.00	1.00	0.33	1.00					
A4																		
A5																		
A6																		
A7																		
A8																		
A9																		
B1	0.67	0.67								0.67	0.67	0.67	0.33					
B2	0.33	0.33								1.00	1.00	0.33	0.67					
B3	0.33	1.00								0.33	0.33	0.00	0.33					
B4	0.33	0.67								0.33	0.33	0.33	1.00					
B5	0.00	1.00								0.33	0.33	0.33	0.33					
B6																		
B7																		
B8																		
B9																		
C1	1.00	1.00								1.00	1.00	1.00	0.67					
C2	0.00	0.67								1.00	1.00	1.00	1.00					
C3	0.00	0.33								0.67	0.67	0.67	0.67					
C4	0.00	1.00								1.00	1.00	1.00	0.67					
C5																		
C6																		
C7																		
C8																		
C9																		

R3C DASHBOARD | Visualise Results

The R3C-GeoResilience consists of 3 fundamental files:

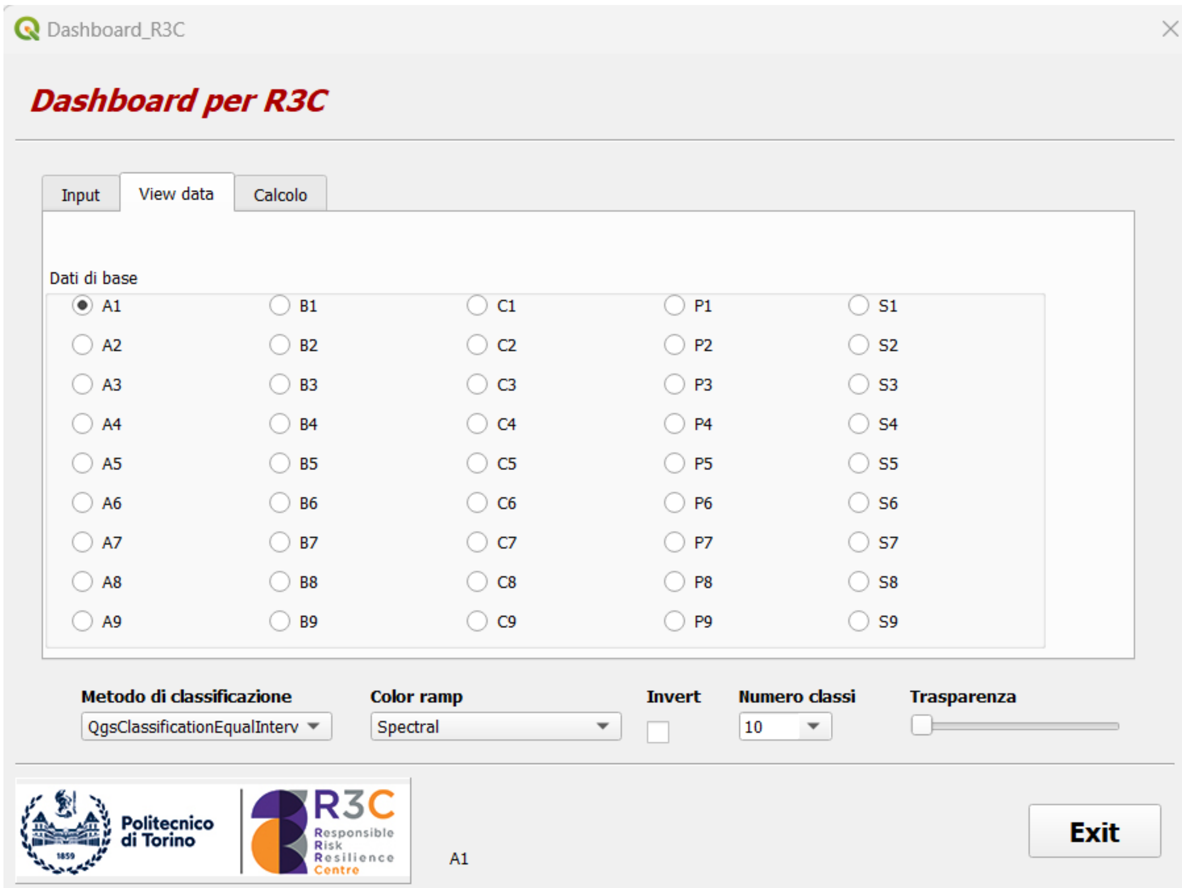
1. The GRID shapefile, including all the layers
2. The shapefile of the boundary of the territory under study
3. The Excel file, including the indicators and the weight of the indicators

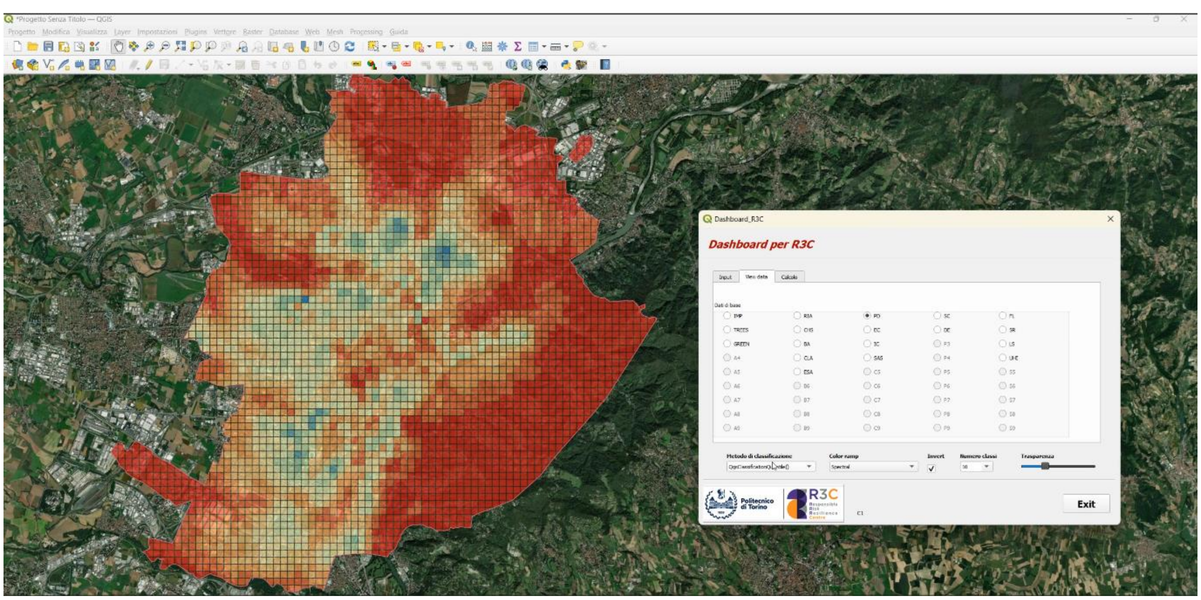
1. Insert data

Add all the files and press send

2. Visualise the vulnerability map of a single indicator

On this tab, you can visualise the vulnerability map of single indicators. In addition, it also allows for the interaction of classification, colours, and transparency.

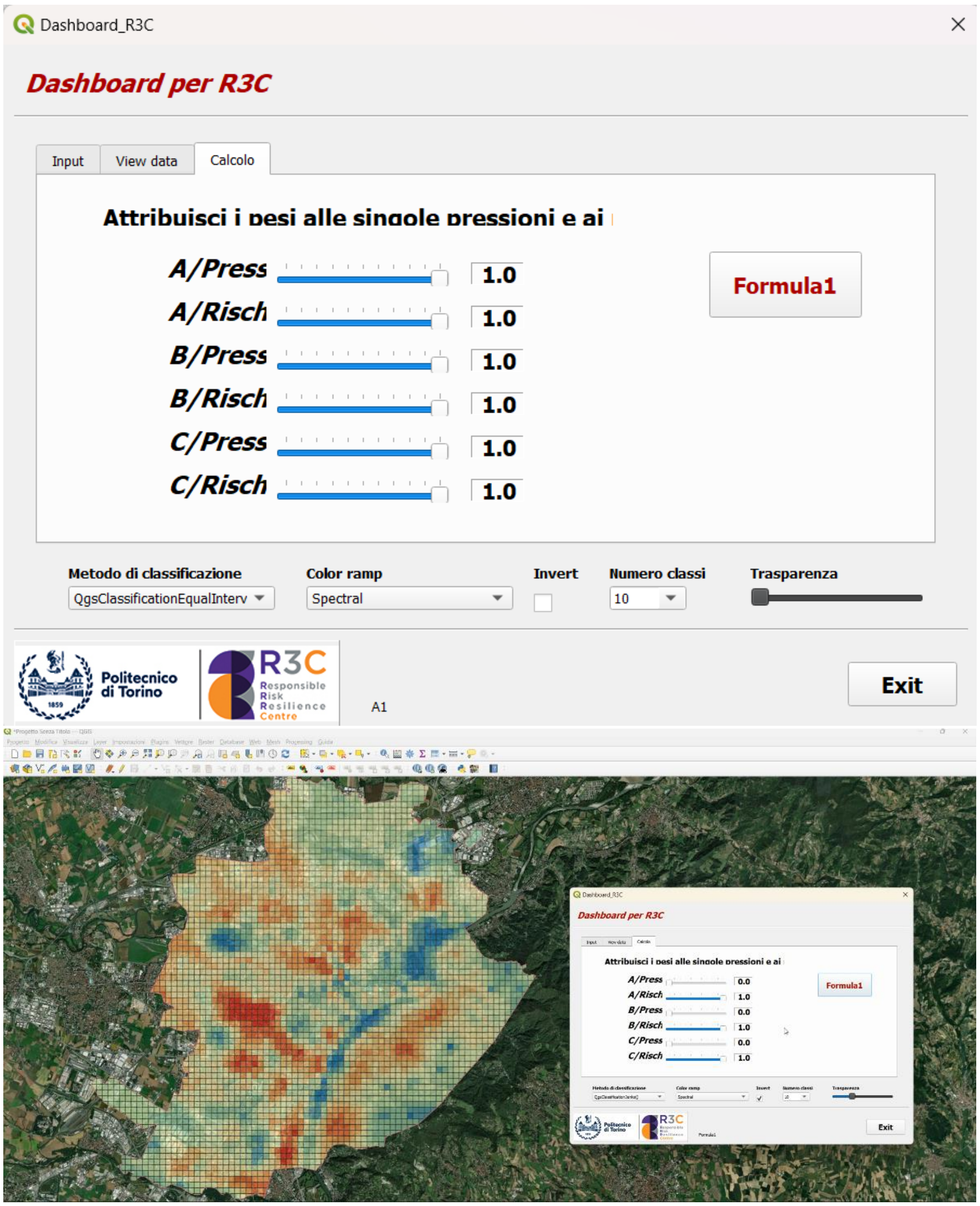




3. Visualise the territorial vulnerability map

In the third tab, click "Run Calculation" to view the overall vulnerability map of the territory. This map combines all the individual indicators from the previous tab and considers the correlation value of the indicators (if inserted in the last sheet of the Excel file).

Additionally, for each sensitivity component, there is a bar where you can assign a weight from 0 to 1 based on your preference. For example, if you want to visualise only the vulnerability of your territory due to environmental sensitivities (component A), you should set the value to 1 for the first two bars and 0 for the rest. Another example is if you want to visualise the vulnerability only to shocks. In this case, set the second, fourth, and sixth bars (referring to shocks) to 1 and the rest to 0.



R3C DASHBOARD | Key Concepts

❖ RESILIENCE

The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation (IPCC, 2014).

❖ VULNERABILITY

Vulnerability if the propensity or predisposition to be adversely affected. It encompasses a variety of concepts and elements including sensitivity (IPCC, 2022). The methodology of R3C considers vulnerability as a function of sensitivities, hazards and pressures.

❖ SENSITIVITY

The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2014).

❖ HAZARD

The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, *livelihoods*, service provision, *ecosystems* and environmental resources (IPCC, 2014). According to R3C methodology, Hazard can be due to either chronic stress or an acute shock.

❖ ACUTE SHOCK

A sudden, intense, and often unexpected event that has immediate and significant consequences for human societies, ecosystems, or the environment (100 Resilient Cities, 2019). Shocks are unpredictable and dangerous events that threaten the system occasionally with a high impact on the environment, settlements, and populations (IPCC, 2021). They are intended as catastrophic events that the system should absorb in adverse conditions. Since the occurrence of shocks is viewed over a long time, their effects are often unpredictable.

❖ PRESSURE

Pressures are linear and predictable trends that affect the system, gradually altering its condition (IPCC, 2012). The pressures affecting the components of the system progressively increase their sensitivity, making them more vulnerable to more significant events represented by Hazards. In addition, they follow specific temporal behaviours, in some cases described by literature (i.e., soil consumption and population ageing), in other cases more difficult to understand (i.e., obsolescence of buildings). Moreover, pressures enable the construction of future vulnerability scenarios at a given time. Pressures are driven by chronic stressors, which are the persistent, long-term impacts on societies, ecosystems, and the environment over an extended period (100 Resilient Cities, 2019).