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GUIDELINES, PRINCIPLES, AND STANDARDISED PROCEDURES FOR CLIMATE ANALYSIS AND VULNERABILITY ASSESSMENT AT REGIONAL AND LOCAL LEVEL / BRIEF VERSION

Con il contributo dello strumento finanziario LIFE dell'Unione Europea
With the contribution of the LIFE financial instrument of the European Community

LIFE MASTER ADAPT – MAinStreaming Experiences at Regional and local level for ADAPTation to climate change - LIFE15 CCA/IT/000061

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BRIEF VERSION OF

"GUIDELINES, PRINCIPLES, AND STANDARDISED PROCEDURES FOR CLIMATE ANALYSIS AND VULNERABILITY ASSESSMENT AT REGIONAL AND LOCAL LEVEL"

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This document represents the second deliverable of action A1 *Climate analysis and vulnerability assessment at Regional level*. It is based on the experience gained by the partnership during the implementation of the first deliverable "*Report on climate analysis and vulnerability assessment results in the pilot Region (Sardinia Region) and the areas targeted in Action C3* ".

This document aims to provide regional and local administrators – dealing with institutional processes aimed at adaptation to climate change in their territories – with the essential elements to define a scientific knowledge framework that can aid in planning the most appropriate adaptation measures.

The document's structure reflects the approach proposed in Action A1, which identifies two sub-actions:

A. climate analyses (past and present trends, future scenarios);
B. vulnerability assessment.

Analysing the past climate and predicting future scenarios

The observation of past climate change and the estimation of future changes is the prerequisite for predicting impacts on the territory and defining strategies/plans for adaptation to climate change.

Reconstructing the past climate is the primary source of information and makes it possible to assess whether any climatic signals can be identified in the territory.

The main critical aspect of the analysis is the availability of a representative data set for the region under examination, that meets the quality, completeness, and continuity requirements.

The prediction of future climate change is based on climate model projections.

The following are used for this purpose:

- **Atmosphere/Ocean General Circulation Model (AOGCM)**: A model that is representative of the average characteristics of past and recent climate, with a horizontal resolution of 250–600 km; not very suitable to assess climate change on the regional scale. The model does not include physical processes that occur at a smaller scale than its resolution.
- **Regional Climate Model (RCM):** A model that provides a better simulation of phenomena on a regional and local scale, with a higher resolution (10–50 km) and a more complete representation of physical processes. **It provides climate projections on a specific area of interest**.

Climate trend analysis

Past and current climate changes are studied using statistical techniques to identify and estimate trends and involve several phases:

- Check of data quality (temperature and precipitation) from available stations and selection of the series that are suitable for analysis, according to length, completeness, and continuity criteria;
- Verification of the homogeneity of the series, using statistical tests and the support of available metadata;

- Calculation of extreme indexes[1] (temp. and precipitation);
- Calculation of regional series, both average values and extreme indexes (temp. and precipitation);
- Assessment of the trends of the regional series, using statistical methods of trend recognition and estimation.

A summary of the average climate values and extreme indexes is published annually by ISPRA in the specific Report "*Climate indicators in Italy*".

Future climate projections

Model projections provide indications of possible climate change for the coming decades, concerning different assumptions of global socio-economic development, taking into account several variables including technological, energy and land-use change, greenhouse gas emissions and air pollutants.

The Intergovernmental Panel on Climate Change (IPCC) provides future scenarios on a global scale *(Representative Concentration Pathways* - RCP), which are used as input for climate models. The four RCPs include:

- a mitigation scenario (RCP2.6),
- two intermediate scenarios (RCP4.5 and RCP6)
- a high-emissions scenario (RCP8.5).

The most important and up-to-date source of model projections for the Mediterranean area is Med-CORDEX, a part of CORDEX *(Coordinated Regional Climate Downscaling Experiment*), whose projections are based on RCP4.5 and RCP8.5 emission scenarios and use high-resolution RCM models. The simulations have a resolution of 50x50 km and include several models up to the year 2100.

In the LIFE MASTER ADAPT project, the same methodology has been applied as in the ISPRA Report "*Il clima futuro in Italia*" [The Future Climate in Italy], which analyses climate projections for the 21st century. The daily outputs of temperature (max, min, and average) and cumulative precipitation for the Italian territory of the four RCM models in the two emission scenarios RCP4.5 and RCP8.5 were extracted and processed from the set of Med-CORDEX simulations. Both the average values and the ETCCDI extreme temperature and precipitation indexes, significant for the Italian climate, were calculated and reported for three timeframes (2021–2050, 2041–2060 and 2061–2090), in terms of differences from the average value of 1971-2000.

[1] The indexes can be divided into different categories: indexes defined by a fixed threshold value; absolute indexes; percentile-based indexes; duration indexes; other indexes.

Acronym	Institution	RCM	GCM
ALADIN	Centre National de Recherches Météorologiques	CNRM-ALADIN5.2	CNRM-CM5
GUF	Goethe University Frankfurt	GUF-CCLM4-8-18	MPI-ESM-LR
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici	CMCC-CCLM4-8-19	CMCC-CM
LMD	Laboratoire de Météorologie Dynamique	LMD-LMDZ4-NEMOMED8	IPSL-CM5A-MR

Table 1 - RCM models selected by the Med-CORDEX programme for future climate analysis in Italy

The climate projections were made according to the following procedure:

1. Extraction of temperature and precipitation projections from available climate models for the area of interest. Consideration of the outputs of several models, in different emission scenarios (to have also an estimate of the uncertainty);
2. Calculation of average values and indexes that are representative of temperature and precipitation extremes for 30-year timeframes (for example, 2021–2050, 2041–2060 and 2061–2090);
3. Assessment of climate projections in terms of differences between the value of a variable/index over thirty years and the corresponding value in the reference climate period, in order to make the results of the different models comparable.

Definitions and conceptual frameworks on vulnerability and risks related to climate change

The concept and definition of climate "vulnerability" in the Reports that the IPCC has produced in recent decades have evolved. In the V IPPC 2014 Report (AR5), this conceptual reworking defines as "**risk**" what was considered "**vulnerability**" in the IV IPCC 2007 Report (AR4).

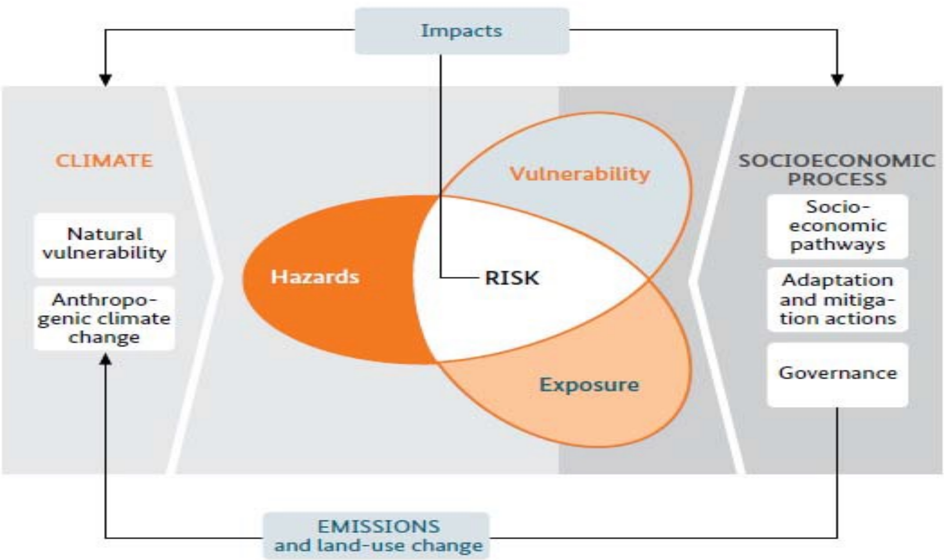

Figure 1 - Illustration of the key concepts proposed by the Intergovernmental Panel on Climate Change (IPCC, 2014)

For the vulnerability analysis performed in Action A1 of MASTER ADAPT, the definition was modulated as follows:

Risk = vulnerability (A) + exposure (B) + hazard (C)

where

- **Risk =** *the potential consequences where something is at stake, and the result is uncertain, recognising the diversity of values. Risk is often represented as the likelihood of occurrence of a hazardous event or trend multiplied by the impacts if such events or trends occur. The risk is determined by the interaction of vulnerability, exposure, and hazard.*

While in the previous conceptual framework (AR4) vulnerability combined exposure, sensitivity and adaptive capacity, in its redefinition (AR5) it is determined on the basis of sensitivity and adaptive capacity according to the following statements:

- **(A) - vulnerability (sensitivity + capacity) =** "*the propensity or predisposition to be negatively affected. Vulnerability includes a variety of concepts and elements including Sensitivity or susceptibility to harm and lack of ability to cope and adapt" and also introducing the concepts of:*
  - ***contextual vulnerability*** *(baseline vulnerability): current inability to cope with external pressures or changes, such as conditions linked to climate change. Contextual Vulnerability is a characteristic of social and ecological systems generated by multiple factors and processes;*
  - ***vulnerability outcome*** *(final vulnerability): the end-point of a sequence of analyses that start with projections of future emission trends, continue with the development of climate scenarios and conclude with studies on biophysical impacts and identification of adaptation options. Each residual consequence resulting from the adaptation defines the levels of vulnerability.*
- **(B) - exposure**: *the presence of people, livelihoods, species and ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, and cultural assets in places and contexts that could be negatively affected*
- **(C)** - **hazard***: the potential occurrence of a natural or human-made physical event or trend or physical impact that could result in loss of life, injury, or other health impacts, as well as damage to or loss of property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. Physical events linked to climate or trends or their physical impacts.*
- **sensitivity:** *the degree to which a system or species is affected, both negatively and positively, by climate variability or change. The effect may be direct [i.e., a change in crop yield in response to a change in average temperature or its variability] or indirect [i.e., damage caused by an increase in the frequency of coastal flooding due to sea level rise]*
- **capacity***: (the ability to cope + adaptive capacity): is the ability of societies and communities to prepare for and respond to current and future climate impacts. It includes:*
  - ***the ability to cope****: the ability of people, institutions, organisations, and systems to address, manage and overcome adverse conditions in the short to medium term, using available skills, values, beliefs, resources and opportunities (i.e. early warning system);*
  - ***the adaptive capacity****: the ability of systems, institutions, human beings, and other bodies to adapt to the potential harm, take advantage of opportunities, or respond to its consequences (i.e. knowledge to introduce new agricultural methods). This second type of capacity has already been defined and used within the 2007 IPCC framework and is, therefore, the most widely used to date.*

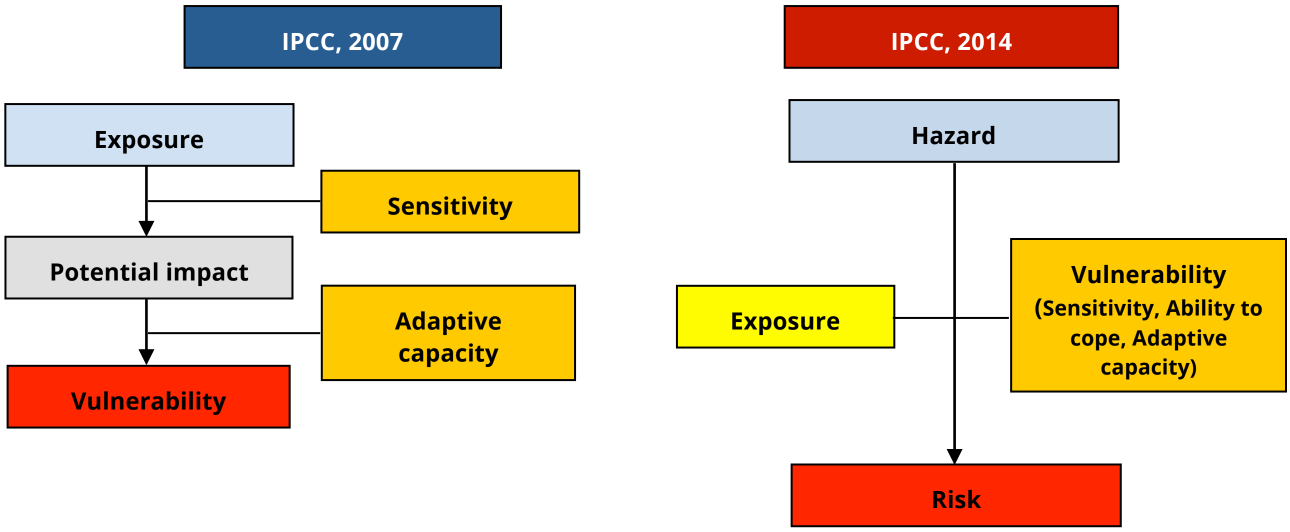

Figure 2 - Comparison of climate change vulnerability factors (IPPC 2007) and risk linked to climate change (IPPC 2014)

Both *frameworks* distinguish causes outside the system linked to climate, but in both cases, only the combination of all the components makes it possible to outline the final result: **vulnerability** or **risk.**

Table 2 - Comparison of the meanings of key concepts in IPCC 2007 and IPCC 2014 reports

EXAMPLE		IPCC 2007	IPCC 2014
External climatic signal	Scarcity of rainfall	Exposure	Hazard
Direct physical impact	Drought	Potential impact	Hazard
Sensitivity	Type of crops	Sensitivity	Vulnerability (Sensitivity)
Capacity	Knowledge of water management	Adaptive capacity	Vulnerability (Capacity)
Presence and relevance of the exposed elements	Relevance of small farms	Implicitly included in Sensitivity	Exposure
Final result	Water scarcity in agriculture	Vulnerability	Risk

Vulnerability assessment: qualitative and quantitative approaches

Vulnerability is not a measurable feature of a system and cannot be easily expressed with a number, but should be interpreted mostly through the description of a situation or condition and based on the interaction of several factors together.

When talking about vulnerability the factors to consider are, therefore:

- *who/what is vulnerable*: an ecosystem, a species, a portion of the population, an economic sector, etc.;
- *to what the system might be vulnerable (the potential causes of the damage)*: causes external to a system such as a storm, an intense rainfall, a heatwave which, depending on its intensity and duration, could be responsible for significant consequences, such as loss of life, environmental damage, loss of biodiversity, economic damage, etc.
- *a time reference*: to which timeframe the vulnerability (present or future) refers.

An in-depth understanding of how a sector/system/territory behaves in relation to climate change helps to set objectives and provide the factors needed to plan adaptation measures, raise community awareness and monitor and evaluate adaptation policies.

Without a proper assessment of the vulnerability and of the risks linked to climate change, it is not possible to identify the most effective adaptation measures to be implemented in a given territory.

The methodological approach for the vulnerability analysis of the MASTER ADAPT project

There are many examples in the international scientific literature of both qualitative and quantitative vulnerability assessments.

MASTER ADAPT's Action A1 *Climate analysis and vulnerability assessment at the regional level* involved the implementation of a quantitative vulnerability assessment within the project's target areas:

- Sardinia Region;
- Metropolitan Network of North Sardinia;
- Metropolitan City of Cagliari;
- Metropolitan City of Venice;
- Aggregation of Municipalities in Northern Milan;
- Union of Municipalities in Northern Salento.

Launched in October 2016, the analysis was carried out based on the definition of vulnerability proposed most recently by the IPCC (AR5 of 2014), referring to the methods used to process and aggregate the indicators proposed in the framework of previously tested methods.

The critical methodological issues found highlighted how there are several issues that need to be solved to make this type of assessment more accessible to regional and local administrations that want to undertake a process of adaptation to climate change.

Based on the experimentation carried out, these Guidelines illustrate, in **seven steps,** the methodological process used for the vulnerability assessment, providing a description of the indicators and the method used to process the synthetic indexes:

- *Step 1: Characterize the context from an environmental and socio-economic point of view*
- *Step 2: Identify climatic hazards*
- *Step 3: Identify the potential impacts*
- *Step 4: Identify the exposed elements*
- *Step 5: Assess the sensitivity*
- *Step 6: Assess adaptive capacity*
- *Step 7: Assess vulnerability to climate change*

The proposed assessment of climate change vulnerability is based on the identification and selection of some indicators to be used as proxies to describe a phenomenon and/or specific characteristics of a system or territory (Steps 1-2-3), to identify and assess the main factors and assets of the system most affected by climate change (Step 4), to assess sensitivity to climate change damage (Step 5), and the ability to respond and adapt to climate change (Step 6). The process is completed in the last step (Step 7) with the final vulnerability assessment.

For each action, through successive and consequent steps, the individual indicators must be processed to complete the final vulnerability calculation:

1) Data collection;
2) Normalization and alignment of indicators;
3) Weighting of the indicators;
4) Calculation of the Global Index and presentation of results.

1. Data collection

At least one indicator for each category (exposure, sensitivity, and adaptive capacity) must be selected. Helpful elements for the selection of indicators are provided in Steps 4, 5, and 6. The data leading to the determination and calculation of each indicator or each indicator selected must be found.

Depending on the potential impact of climate change considered in the vulnerability analysis, there may be different types of data (for example, specific, geo-referenced, etc.), but it is important that they respond suitably to the needs of the analysis.

Some characteristics to consider are:

- ensure suitable spatial and temporal resolution;
- present continuity (no data gaps in the database);
- accessibility (coming from an easily accessible database);
- provide up-to-date information;
- reliability.

Data can come from a variety of sources including, for example:

- regional and local documentation;

- sector-specific studies;
- Italian National Institute of Statistics (ISTAT);
- Istituto Superiore per la Protezione e la Ricerca Ambientale [Institute for Environmental Protection and Research] (ISPRA);
- Agenzia Regionale per la Protezione Ambientale [Regional Environmental Protection Agency] (ARPA);
- available web portals and/or geo-databases;
- data from remote sensing analysis.

2. Normalization and alignment of indicators.

The indicators selected for each category (exposure, sensitivity, and adaptive capacity) must be standardised to develop a synthetic global index and to be able to calculate the final vulnerability indexes.

The aim of standardisation is to transform the values of the indicators, measured at different scales and in different units, into comparable values on a common scale (values between 0 and 1).

The value 0 represents the optimal level, while the value 1 represents the most critical situation.

Depending on the measurement scale, different standardisation methods can be used.

Normalization of the metric indicator values.

Indicators measured using a metric scale (for example, temperature, precipitation) are generally normalized by applying the Min-Max method, using the following formula:

Xi, from 0 to 1 = (Xi - Xmin)/(Xmax - Xmin)

where,

Xi, from 0 to 1 = the new normalized value

Xi = the data point to transform

Xmin = the lowest value for that indicator

Xmax = the highest value for that indicator

The standardisation process transforms the values of the indicator into standardised values from 0 to 1, subtracting the minimum value and dividing by the *range* of values of the indicator.

These new values must be "aligned" between the different indicators so that "the direction" of the range is the same for all indicators in the same category;

***vulnerability*: low values =**positive conditions
high values = negative conditions
the higher the value, the greater the vulnerability.

adaptive capacity: low values = positive conditions
high values = negative conditions
the lower the value, the greater the adaptive capacity

In this case the range of values of the indicator must be inverted so that the lowest value is represented by the value 1 and the highest value is represented by the value 0. This inversion is applied by subtracting the value of the indicator from 1.

The greater the adaptive capacity, the lower the vulnerability.

Normalization of category or nominal indicator values.

Category indicators (for example, educational level) and nominal indicators (for example, crop type) are normalized by assigning them to five classes, with the lowest class representing optimal conditions and the highest class representing the most critical conditions, as in the following outline:

CLASS NO. DESCRIPTION

1 Optimal

2 Quite positive

3 Neutral

4 Quite negative

5 Critical

The values classified in the five classes must then be fit back into the range from 0 to 1 (as shown in the table below) in order to be comparable with themselves and with the other metric indicators.

CLASS N. VALUE DESCRIPTION Indicator range

(0-1)

1 Optimal 0–0.2 0.1

2 Quite positive 0.2–0.4 **=>** 0.3

3 Neutral 0.4–0.6 0.5

4 Quite negative 0.6–0.8 0.7

5 Critical 0.8–1 0.9

3. Weighting of the indicators

If some indicators are considered more important than others, weights should be assigned to each indicator to identify their greater (or lesser) influence in the assessment. Greater weight means more influence of that indicator for the analysis and vice versa. The weights to be assigned to the indicators can be different among individual indicators or the same (in this case, the various indicators will have the same influence for the analysis). It is advisable to assign different weights to the indicators so that they reflect their real (and different) importance.

Also in the weighting process a *participatory approach* involves stakeholders and experts (for example, through workshops or questionnaires) to foster a transparent and shared process of recognition of the most relevant indicators for each phenomenon. This approach guarantees robustness in the analysis and a reduction of possible conflicts since it is the result of full sharing and acceptance of both the methodology and the results produced.

Within MASTER ADAPT, a tool based on a statistical approach, specifically the **AHP (Analytic Hierarchy Process) method** was used to assign weights to the indicators for the North of Milan target area.

AHP Method

Calculation of the Global Index and presentation of results. The indicators previously normalized and fit back into the range 0-1 must be aggregated to calculate the three Global Exposure, Sensitivity, and Adaptive Capacity Indexes and for the final calculation of the Global Vulnerability Index. AHP is a method for transposing subjective opinions into measurable numerical relationships. Mathematically, AHP is based on the solution of a so-called Eigen value problem.

4. Calculation of the Global Index and presentation of results

The indicators previously normalized and fit back into the range 0-1 must be aggregated to calculate the three Global Exposure, Sensitivity, and Adaptive Capacity Indexes, combining the last two for the final calculation of the Global Vulnerability Index.

Two methods of aggregation are proposed:

Weighted arithmetic aggregation

Global Index = $(E_1 * w_1 + E_2 * w_2 + \ldots E_n * w_n)/(w_1 + w_2 + \ldots + w_n)$

Weighted geometric aggregation

Global Index = $(N_1\text{^}w_1 * N_2\text{^}w_2 * N_3\text{^}w_3 *\ldots* N_n\text{^}w_n)\text{^}(1/(w_1 + w_2 + w_3 +\ldots+w_n))$

The values of the calculated Global Indexes can be used and represented in several ways, based on the purpose of the analysis. Tabular representations of indicator summaries, maps with different spatial resolutions (regional, municipal, or sub-local), graphical representations for each indicator or with summaries of the different Global Indexes, are commonly used to represent the results of the analysis.

Step 1: Characterize the context from an environmental and socio-economic prospective

The first step (*Characterize the context from an environmental and socio-economic point of view*) to assess the vulnerability and risks of a territory due to climate change consists in the analysis of the context, such as the circumstances and situations in which a phenomenon occurs. It is, therefore, a matter of summarizing and interpreting how the qualities, sensitivities, and critical issues of a territory contribute to influencing its resilience, i.e., its ability to respond to external stress factors.

This must be done by selecting and populating a suitable set of indicators that can help to interpret the current situation, understand current trends, and monitor the plan's actions during their development. Indicators can be considered parameters, i.e., measured or observed properties, or data, arising from the processing of one or more parameters. Moreover, they can have a direct relationship with the phenomenon to be measured or an indirect relationship: they are therefore proxies, indirect approximations of the phenomenon itself.

It is helpful to take into account three requirements when selecting indicators: relevance and usefulness, analytical consistency, and measurability. The indicator must therefore be able to adequately represent the phenomenon, be easy to interpret and represent variations in time and space, be reliable from a theoretical and scientific point of view, and be based on reasonably available, documented, and regularly updated data.

Once the indicators have been collected and populated, to consistently represent different topics, it will be appropriate to draw up a context analysis report describing the results of the analysis made on the individual indicators.

The guidelines suggest an initial possible set of indicators that can be populated at all administrative levels, available in the original document on pages 45-50, as described for example in the following table (*Environmental and socio-economic indicators - Production structure).*

Topic	Indicators	UoM	Historical series	Source of data	Relationship with subsequent steps
Production structure	Number of active units and change thereof	no. / %	Last two surveys of industry and services	Istat	Step 4: Exposed factors
	Number of employees and change thereof	no. / %	Last two surveys of industry and services	Istat	Step 4: Exposed factors
	Number of people employed in the construction sector and change thereof	no. / %	Last two surveys of industry and services	Istat	Step 4: Exposed factors

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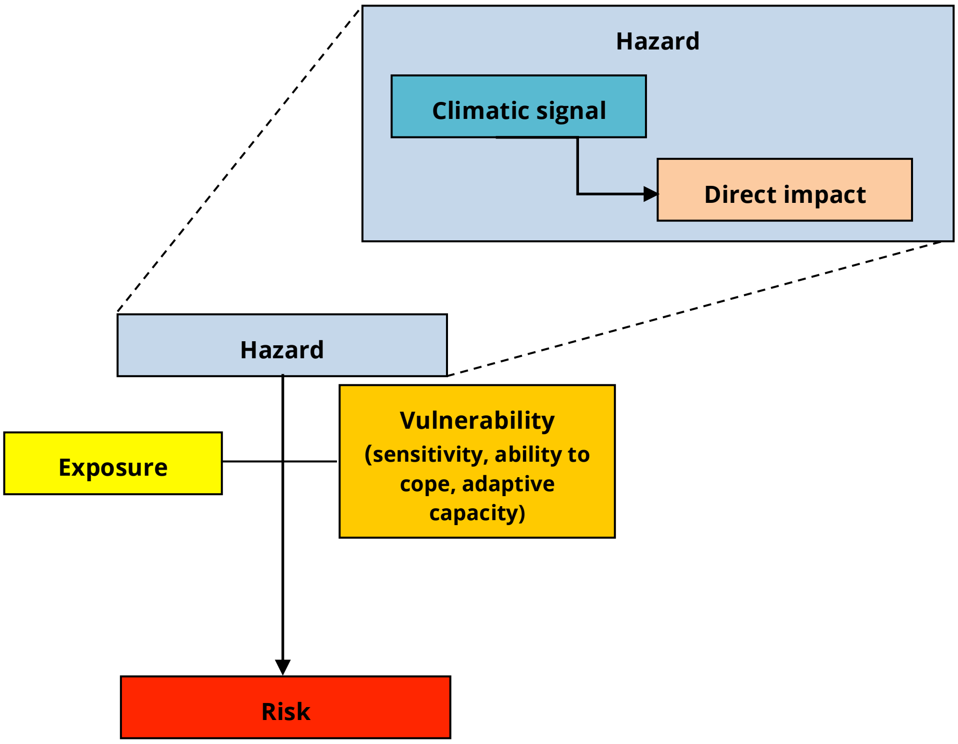
Topic	Indicators	UoM	Historical series	Source of data	Relationship with subsequent steps
	Number of people employed in the transport and construction sector and change thereof	no. / %	Last two surveys of industry and services	Istat	Step 4: Exposed factors
	Number of people (family labour force + other farm labour force on a continuous + occasional basis)	ha / %	Last two surveys of agriculture	Istat	Step 4: Exposed factors

Step 2: Identify climatic hazards



The second step *(Identify climatic hazards)* involves investigating the climatic factors that influence a given area and their change in the future. The hazards result from the close link between climatic signals and direct impacts to the extent that it is difficult to make a clear distinction between the two factors. The former consist of climate values that may indicate climate change, while the latter are the impacts resulting from the occurrence of a climatic signal.
A hazard is an element that cannot be influenced at source by adaptation actions. It is important to take this into account because knowledge of a given phenomenon makes it possible to understand how to act to prevent, mitigate, or avoid the risks caused by an impact.

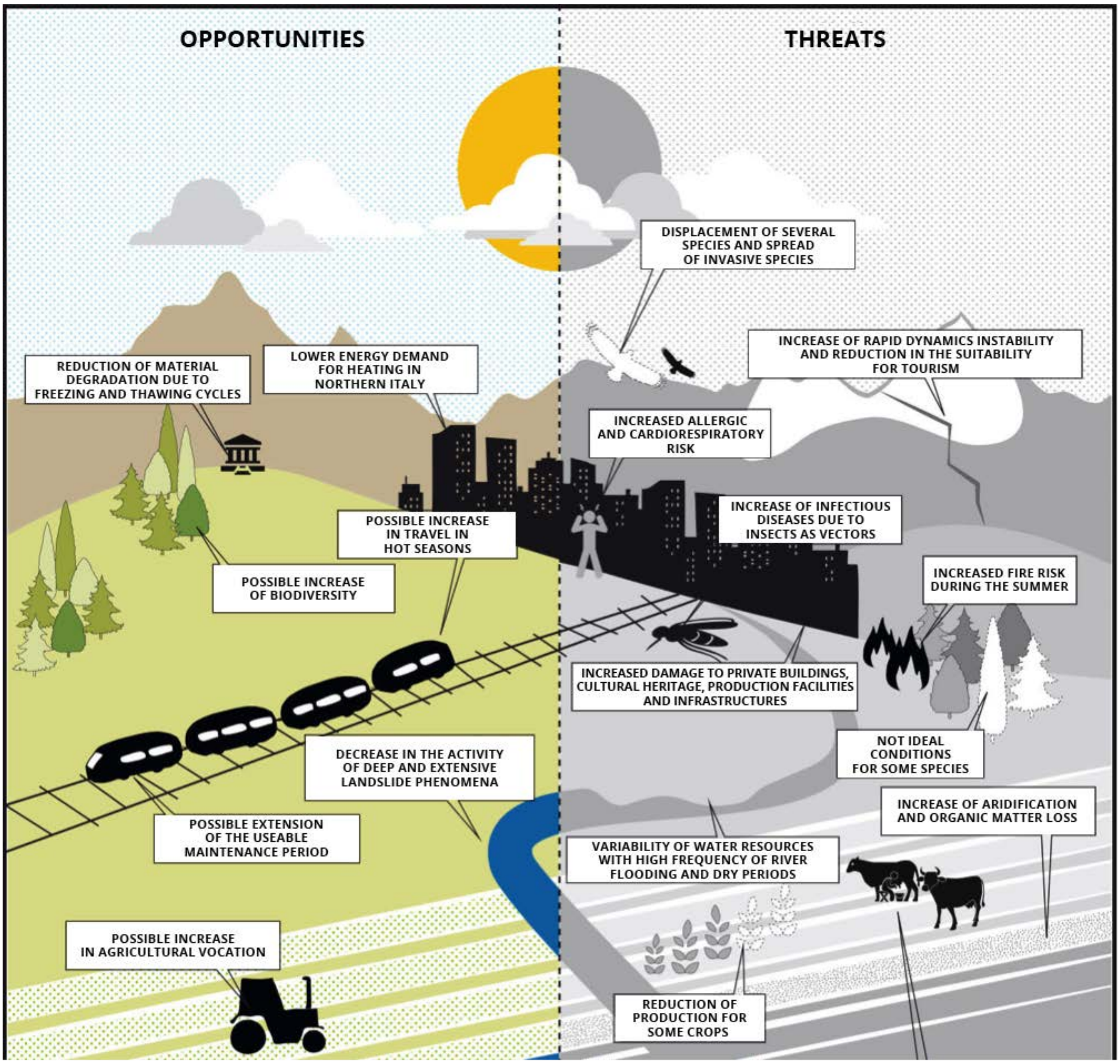
Climatic signal	Direct impact	Risk
not affected by adaptation measures	*not affected by adaptation measures*	*influenceable through risk mitigation and adaptation measures*
Global increase in annual average temperatures	Increase in the volume of oceanic and sea waters, rising ocean and sea levels	Damage caused by the "high water" phenomenon in Venice
High number of consecutive days without rain	Deficit in natural water supply to the soil	Decrease in agricultural yields due to the inability of available water resources to meet irrigation demand

This table shows some illustrative examples of the link between climatic signal, direct impact, and risk. Here are the two guiding questions to identify the hazards:

- *in the past decades what kind of dangers related to climatic signals have occurred in the area being analysed?*
- *how are the climatic hazards expected to change in the area under study in the coming decades?*

As far as the use of indicators is concerned, the document indicates as references for climatic signals, tables 1 and 2 on pages 14 and 15, respectively. Two fundamental documents at the Italian level, the SNACC (National Strategy on Adaptation to Climate Change), and the PNACC (National Plan for Adaptation to Climate Change), are indicated as sources. The latter, in particular, defines uniform climate areas. In addition to this, it is advisable to consider the scientific literature in the climate field, which over the years, will provide more up-to-date analysis. Lastly, it is advisable to establish a discussion and participation process with the territory, starting with this step.

Step 3: Identify the potential impacts



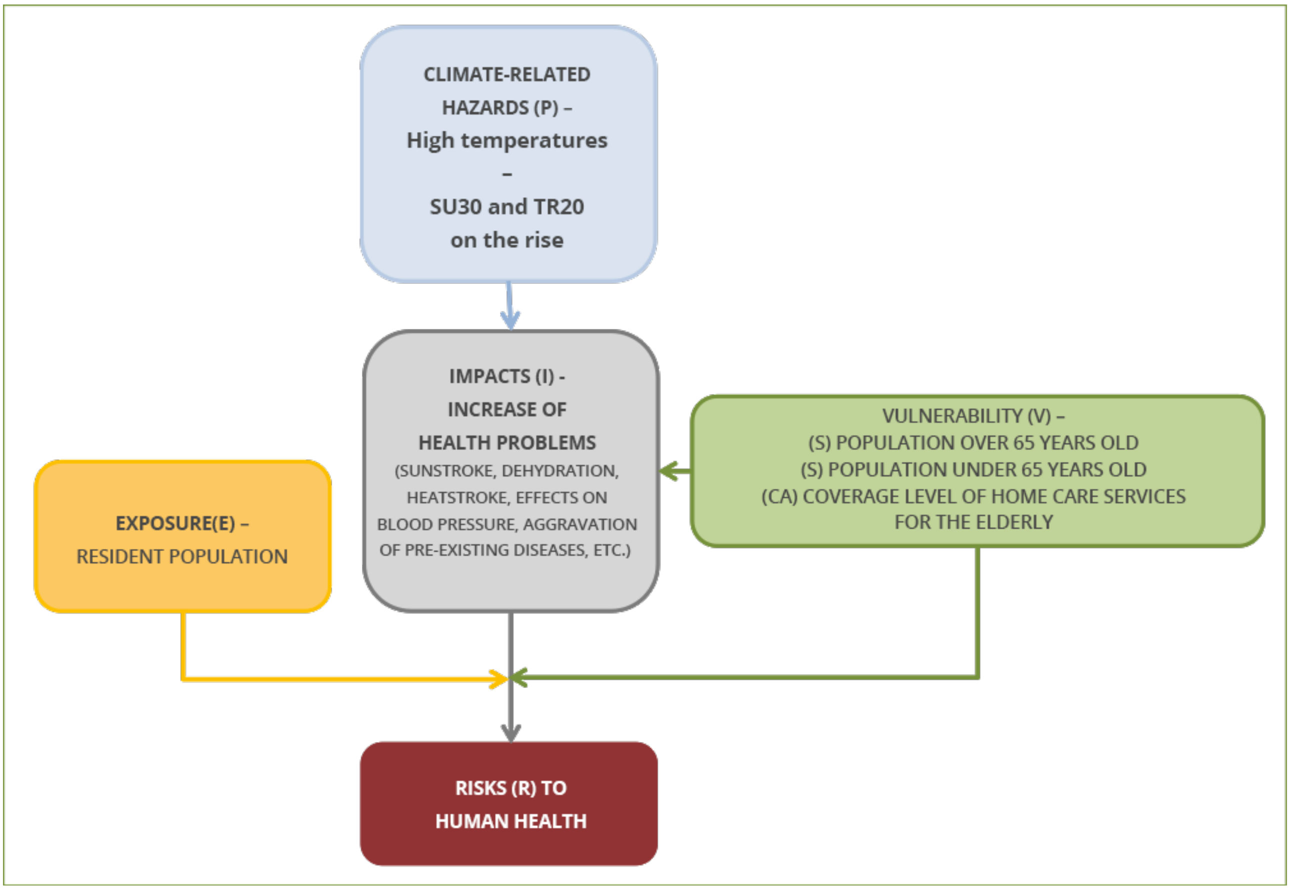
Step 3 *(Identify the potential impacts*) concerns a type of impacts other than those indicated above, the potential or intermediate impacts which, unlike direct impacts, may be affected by adaptation actions. The impacts are identified on the basis of the work done in the previous steps and thanks to an analysis of the available documentation, limited to the area of interest.

The three guiding questions for the identification of potential impacts:

- *Are there identifiable impacts resulting from climate phenomena in relation to the territory being studied in previous decades?*
- *What types of resources or opportunities were affected as a result of those impacts?*
- *Which socio-economic sectors were affected as a result of those impacts?*

Concerning the construction of quantitative indicators to define potential impacts, a table on page 65 shows some examples, indicating: Description of potential impact, quantitative indicator, and period. In addition to the above, other primary sources are environmental and socio-economic documents and data produced by local and national institutions and research centres, among which the PNACC is worth mentioning. In terms of participation, it is important at this stage to broaden the range of players involved in the process in order to gather more information about the territory being analysed.

Step 4: Identify the exposed elements

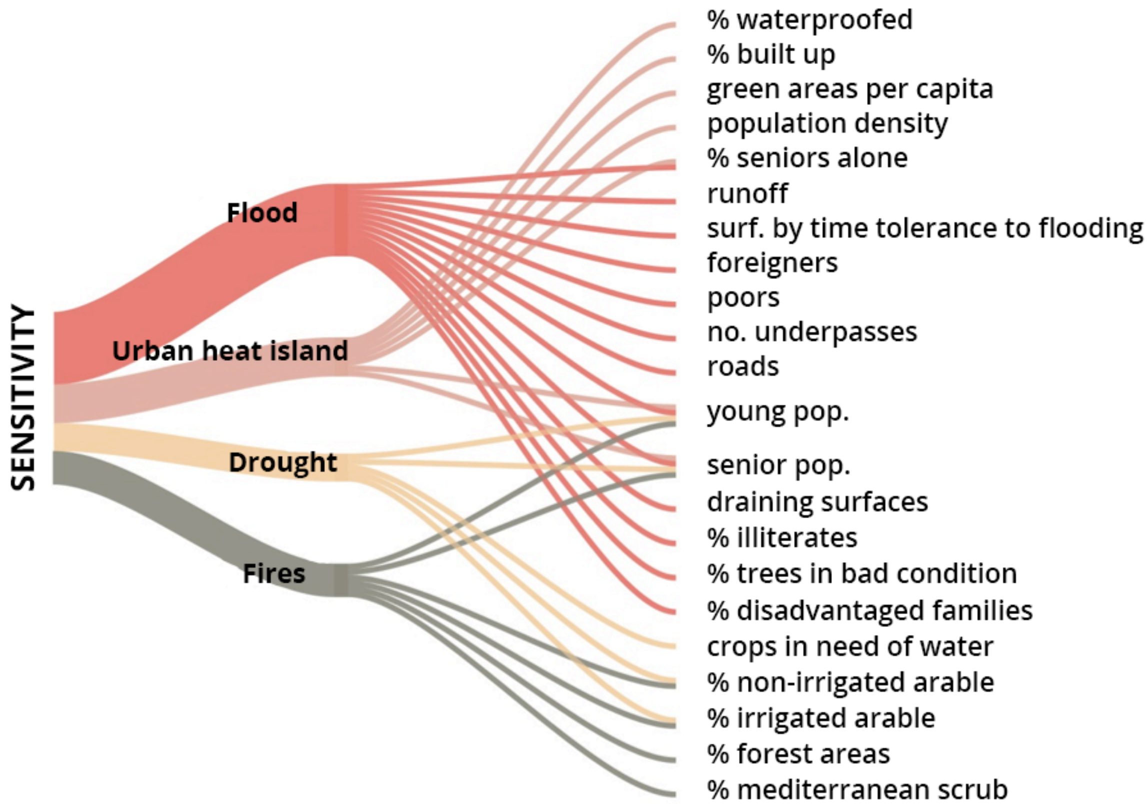


The fourth step (*Identify the exposed elements*) concerns the concept of exposure to climate change. An exposed element is a person, thing, or resource that can be negatively affected by the effects of climate change, for example, the population living in a given area. In this sense, it is distinct from other elements that are similar but related to vulnerability, which as shown below is a separate step from the one presented here.

A good starting point for identifying the exposed elements is the context analysis performed in the first step. Then, for each risk linked to climate change to be assessed, it will be necessary to understand what the exposed elements are. The table on page 75 illustrates the four categories (natural, human, infrastructural, financial, and economic capital) of exposed elements to be analysed in relation to the environmental and socio-economic context of the territory being analysed, together with some examples of exposure indicators. The global exposure index is calculated by the formula described on page 39:

$$\text{Global index} = (E1 * w1 + E2 * w2 + \dots En * wn)/(w1 + w2 + \dots + wn).$$

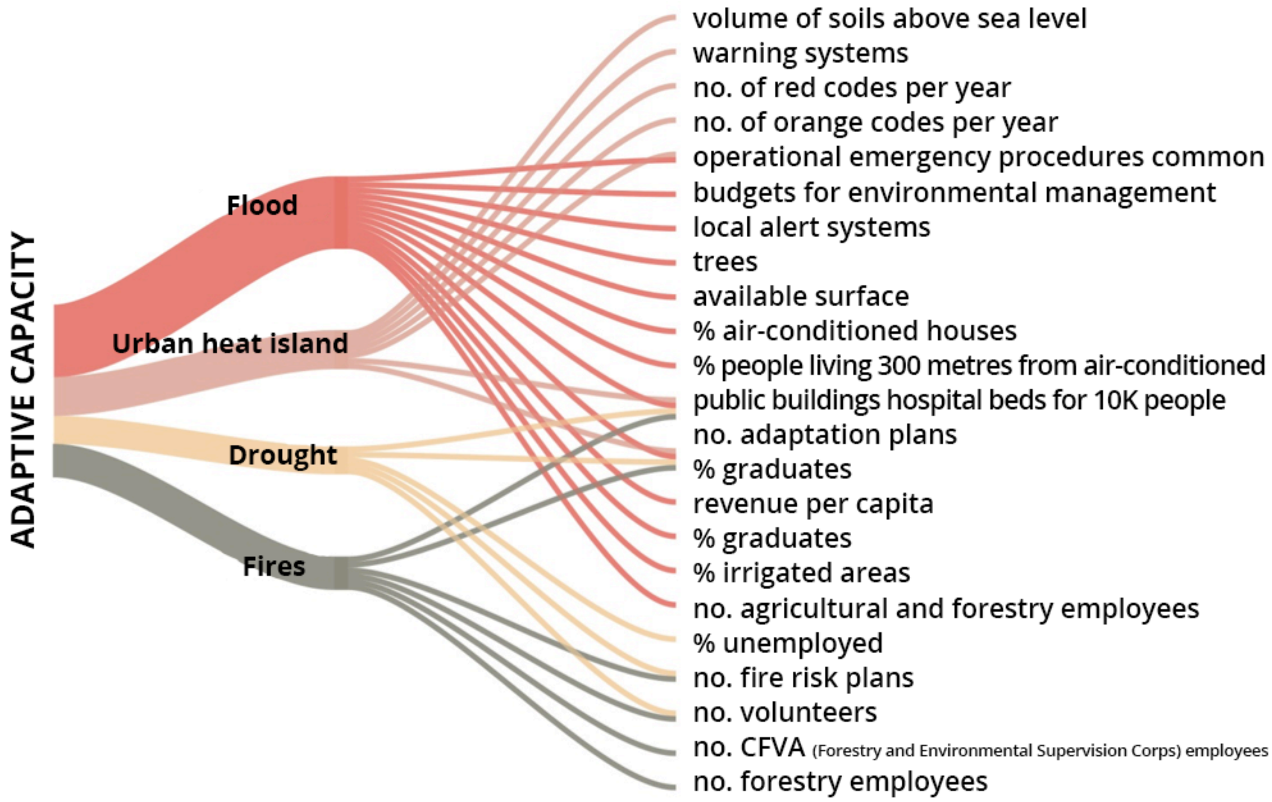
Step 5: Assess the sensitivity



Step 5, *(Assess the sensitivity*) consists of assessing the sensitivity to climate change. The latter is the degree to which a system is positively or negatively affected by climate stimuli, either directly or indirectly. According to the example of the previous step, sensitivity concerns a specific population group, such as the population over 65 years of age.

Again, four categories (natural, human, urban morphological, and economic and financial factors) help to identify sensitivity. A table on page 79 and four diagrams on the following four pages suggest a series of indicators that can help assess sensitivity and exposure. In the choice of the indicator, both the type of impact and, of course, the actual availability of the data in the territory being analysed have a role to play. The global sensitivity index is calculated by the formula: Global index = (E1 * w1 + E2 * w2 + ... En * wn)/(w1 + w2 + ... + wn).

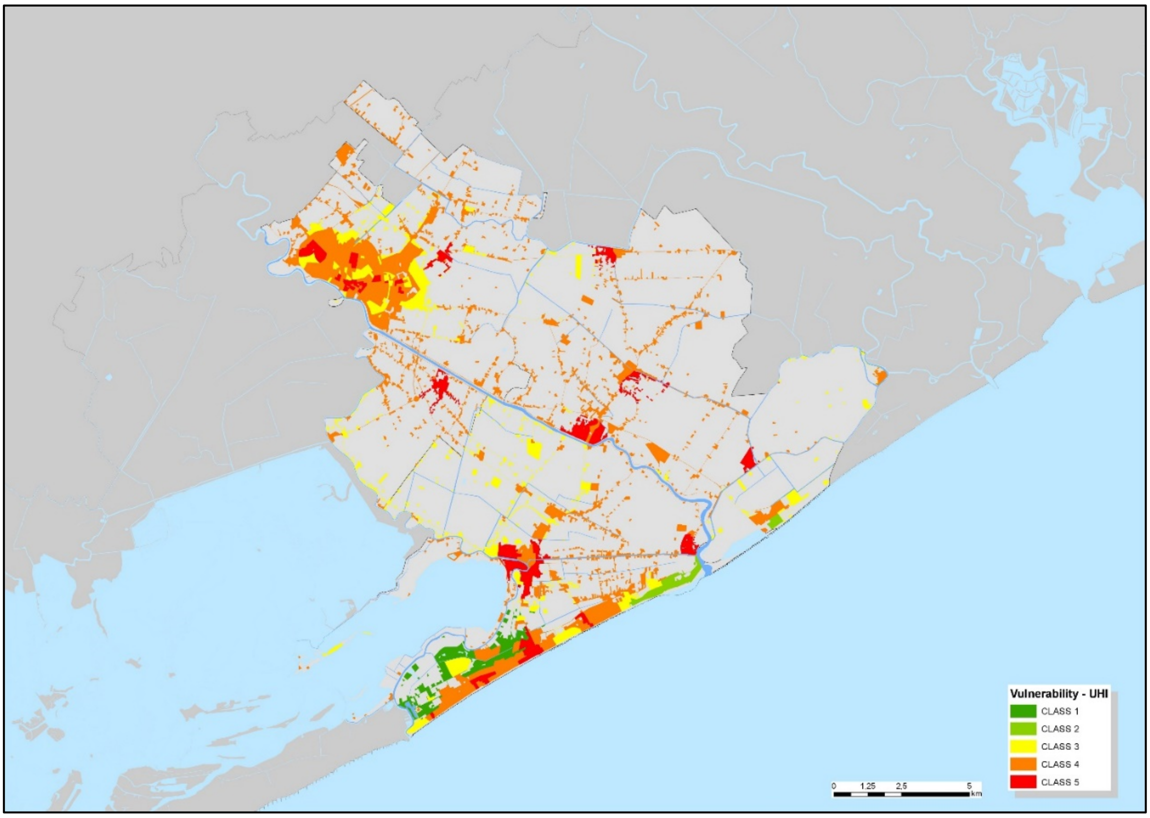
Step 6: Assess adaptive capacity



Step 6, *(Assess adaptive capacity*) concerns adaptive capacity, i.e., the ability of systems, institutions, people, and bodies to adapt to damage, either by exploiting opportunities or by responding to the consequences. Following the example described in step 4, adaptive capacity concerns an even more specific segment of the population, such as those with a given educational qualification.

The four categories in which the dimensions of adaptive capacity are organised are: institutions, knowledge and technology, production/infrastructure, and economic resources. Again, some examples are given in the illustration on page 91. Note the strong interconnection between this step and the step immediately preceding it, which in the application of the guidelines can be carried out in parallel. In this case too, the indicators must be chosen on the basis of the availability of the data in the study area. Of course, in order to represent the adaptive capacity of a system many of the indicators need to be inverted, i.e., subtracting the value from 1: lower values should reflect positive conditions of adaptive capacity, while higher values should reflect negative conditions. The global adaptive capacity index is calculated by the formula: Global index = (E1 * w1 + E2 * w2 + ... En * wn)/(w1 + w2 + ... + wn).

Step 7: Assess vulnerability to climate change



Lastly, the seventh step (*Assess vulnerability to climate change*) concerns the vulnerability assessment, which is the combination of global sensitivity and adaptive capacity indexes:

$$\mathbf{V = (S * w_{s1} + AC * w_{ac}) / w_s + w_{ac}}$$

where

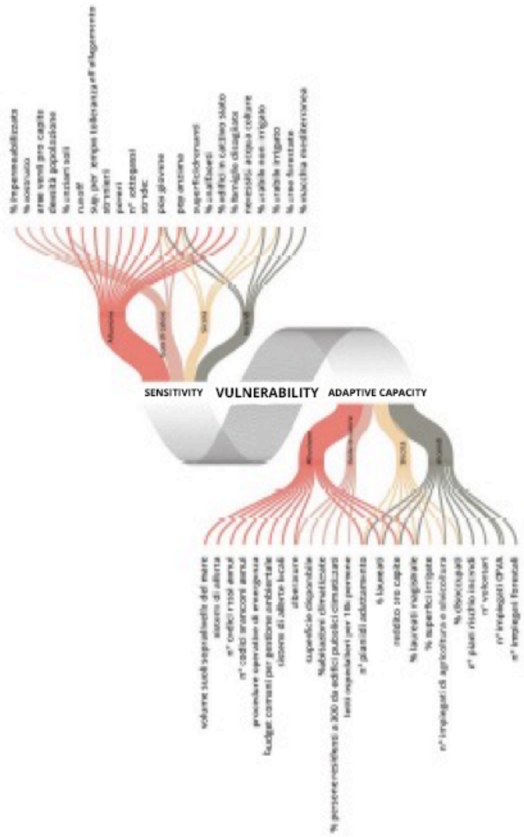
V = is the Global Vulnerability Index

S = is the Global Sensitivity Index

AC = is the Global Adaptive Capacity Index

w_i = is the weight assigned each time to each component (see page 96 of the Guidelines).

The combination of sensitivity and adaptive capacity indicators is shown in the figure "Complete vulnerability assessment scheme with indicators that can be used for each variable (sensitivity, adaptive capacity, and vulnerability) and each impact considered (flood, urban heat island, drought, and fire)" (see page 97 of the Guidelines).



Concluding remarks and future outlook

The implementation of the analyses described in the previous paragraphs has made it possible to test every methodological aspect and to identify strengths and weaknesses.

For example, for climate trend analyses and future climate projections, overcoming critical factors depends to a large extent on dynamics and processes that take place outside the scope of the climate change vulnerability assessments (e.g., improving the availability and quality of historical climate data series, increasing the resolution of freely accessible models for assessing expected changes at the local level).

The development of the Guidelines has brought to light some attention areas.

Climate trend analysis

Strengths

- Robust quality control methodology of the daily series based on tests carried out by European and international institutions responsible for the collection and dissemination of climate data
- Robust statistical methodology to assess climate trends applied to a set of indexes that are representative of average values and climate extremes as defined by the WMO Climatology Commission

Weaknesses

- Poor availability of historical climate data series in some areas
- Several historical series cannot be used because they do not meet the required quality criteria

Future climate projections

Strengths

- Analysis of the RCM projections that participate in the Med-CORDEX initiative, the most important and up-to-date source of model projections on the Mediterranean area and therefore on Italy
- Availability of outputs of multiple models (with 50x50 km resolution) in the two emission scenarios RCP4.5 and RCP8.5 up to 2100; this supports the assessment of the average projection of each variable or index (ensemble mean) and the relative uncertainty (spread)

Weaknesses

- Resolution of the 50x50 km models, too low to assess expected local variations

Vulnerability analysis

Strengths

- Accessible and easy to implement methodology - Possibility to compare different situations based on appropriate indicators
- Results as useful inputs for identifying intervention priorities and preparing adaptation measures

Weaknesses

- Limited data availability for indicator population and need for proxy indicators
- Aggregation of indicators by geometric averaging that is not very representative of a more complex situation- Lack of solid scientific sources in scientific literature to support indicator weighting systems
- Incoherent alignment of indicators with respect to vulnerability (for example, adaptive capacity)
- Results produced in terms of relative vulnerability (red is more vulnerable than green) and not absolute vulnerability (red is highly vulnerable)
- Lack of significant methodologies and approaches for validating the results

The methodology illustrated in these Guidelines is one of the first attempts to quantify the vulnerability levels of a territory and proposes a simplified approach that, however, has difficulty describing the complexity of environmental phenomena and the chain dynamics triggered by climate change.

The reliability of the results depends on the quality of the input data. It is therefore advisable to do all is possible to collect the highest possible quality of data and that is the most significant for the population of suitable indicators, also in order to reduce the use of proxy indicators

Data normalization is also a delicate phase that can negatively affect the significance of the results. The reading of the data obtained varies depending on the threshold values used as minimum and maximum values.

For an assessment to have an absolute connotation, it would be necessary to use specific thresholds that may be proposed in the scientific reference literature or be based on the opinion of experts from the local territorial context.

As far as the weighting of the indicators is concerned, it was considered suitable to consider a weight equal to 1, bearing in mind that this is in any case neither the ideal choice nor the closest to reality. The determinants of Vulnerability do not, in fact, have equal weight in determining the phenomena analysed: the weight that a factor can have depends on the local context as well as the type of other factors at stake against which it is compared.

In this regard, the Guidelines suggest, by way of example, the Analytic Hierarchy Process approach, which can be useful for analysing and supporting the comprehension of complex decision-making problems.

Whatever procedure is adopted, even for weighting, it may still be helpful to consult local experts who can in some way orient and provide guidance on the most correct choices and those that are most realistic.

Lastly, it is still necessary to reflect on the most appropriate approach in order to correctly validate the results obtained. Vulnerability remains a theoretical concept and one that is difficult to "measure". Once more we can consider that the only "verification tools" suitable for this purpose could be based on the knowledge of the territory by local experts who can confirm or reject the reliability of the results vis-à-vis the real situation.

In a future perspective, improving the reliability of vulnerability analyses would mean strengthening the capacity to monitor and assess the changes that will occur over time in a given area, both at the overall value level and at the level of individual indexes and indicators, thus providing the necessary elements for political decision-makers to implement adaptation measures.

NOTES

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MAinSTreaming Experiences
at Regional and local level
for ADAPTation to climate change

Con il contributo dello strumento finanziario LIFE dell'Unione Europea
With the contribution of the LIFE financial instrument of the European Community

LIFE MASTER ADAPT – MAinStreaming Experiences at Regional and local level for ADAPTation to climate change - LIFE15 CCA/IT/000061

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