

Climate Sensitivity Assessment at the Regional Scale for Spatial Planning: A Case Study in Italy

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ABSTRACT

The aim of this research is the quantitative characterization of climate risk, in order to support spatial planners in choosing resilient adaptive actions at the urban and territorial scale. According to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, climate risk is the combination of hazard, exposure, and vulnerability parameters. Vulnerability is a function of the climate sensitivity and the adaptive capacity. From the planners' point of view, climate sensitivity expresses the degree to which the study area is influenced by the climate variability. In this regard, the authors have implemented a GeoDataBase to quantify the climate sensitivity over a southern Italian region, analyzing long-term measured meteorological data (air temperature and precipitation) and subsequently generating synthetic maps by interpolating data. As a result, the authors present climate sensitivity maps of the Calabria region, providing useful physical and data-based identification of priority areas for planning purposes.

KEYWORDS

Spatial Planning, Mapping, Priority Areas, Climate Change, IPCC, Precipitation, Temperature, Calabria Region

INTRODUCTION

Climate change is a global systemic phenomenon (Centeno et al., 2015) defined as a climate state affected by changes in average and varied properties over an extended period of time (Xue et al., 2021).

Spatial planning research combined with climate factor research has received increased attention in recent years (Hurlimann & March, 2012; Isinkaralar, 2023; Jiang et al., 2017; Nadin et al., 2021; Pacala & Socolow, 2004; Wilson, 2006). Therefore, the literature recognizes that although planners are concerned with climate issues, the use of climate information is too often unsystematic (Briley et al., 2015; Eliasson, 2000; Kauffman & Hill, 2021; Measham et al., 2011; Meerow & Woodruff, 2020). According to Manigrasso (2013), a new approach must be adopted in the discipline when searching for new ways of planning to accommodate local vocations and integrate the climate issue.

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This study aims to incorporate climate knowledge into the planning languages, supporting spatial planners in identifying solutions to current and future environmental challenges.

Thus, the research activities of planners and climate specialists are often disjointed. Therefore, the ambition and innovation of the proposed work is to promote integration between these two research approaches in order to plan appropriate risk reduction policies. To this end, a research group was set up through an agreement between the authors' institutions, namely the Department of Civil Engineering of the University of Calabria and the Institute of Atmospheric and Climate Sciences of the National Research Council of Italy. This joint research aims to promote integrated knowledge of climate parameters, with specific reference to precipitation and temperature data; the research designs and implements a GeoDataBase (GDB) to facilitate climate risk assessment at the regional scale. Specifically, it aims to develop domains of climate sensitivity and digital mapping for the area of application coinciding with the Calabria region, which is considered a climate hot-spot. Furthermore, we hope that the expected results can produce successful climate change impact management and further provoke local communities' commitment towards achieving sustainable development goals (Cobbinah et al., 2019).

In light of these assumptions, our contribution is organized as follows. The second section describes the current state of spatial planning in the context of climate change in Italy. The third section summarizes the authors' analysis of the state-of-the-art and presents the design and methods of the research. The fourth section outlines the main results obtained in the context of the trial. The last section discusses the results obtained.

THE CURRENT STATE OF SPATIAL PLANNING ON THE CONTEXT OF CLIMATE CHANGE IN ITALY

Adaptation and mitigation strategies are equally crucial for reducing the adverse impacts of climate change (Hossain et al., 2024). However, as stated by Musco and Fregolent (2014), the international scientific community has repeatedly highlighted the steady progression of climate change and its impacts. It is evident the insufficiency of mitigation policies if not associated with appropriate actions to adapt to the new climate scenario the urban and territorial systems, increasingly affected by extreme and variable weather phenomena. According to the technical summary (Pörtner et al., 2022) of the intergovernmental panel on climate change, adaptation refers to adjustment, moderation, or changes to social and ecological systems to avoid or recover from the effects of climate change. Therefore, planners must define adaptive strategies to be implemented within the framework of planning and management, signaling a new culture of urban design (Musco & Zanchini di Castiglionchio, 2014). Thus, by placing climate change policies at the center of urban policies (Musco & Magni, 2014), researchers in this field can identify the most appropriate ways to design and manage the city in the face of changing climates.

The integration of climate change issues into planning activities is also recognized by the 2030 Agenda under the Sustainable Development Goal 13, which mentions that to achieve a sustainable society, climate change measures need to be integrated into national policies, strategies and planning. However, progress towards this sustainable development objective is still not satisfactory. As stated by Wamsler et al. (2013), current climate adaptation practices do not yet seem to adequately exploit their potential to reduce and adapt to the growing urban risk. To this end, the authors highlight how integrating cutting-edge theoretical and practical knowledge can lead to more comprehensive and appropriate models for adaptation planning. In this sense, planning is an appropriate tool to manage climate impacts (Cobbinah et al., 2019).

The European commitment to making member states resilient to climate change appears intense, as confirmed by the adoption in 2013 and subsequent update in 2021 of the European Union strategy on adaptation to climate change (Ledda et al., 2023). Above all, this priority is related to the promotion and the support of adaptation actions at local levels. Over time, the European Union has focused its

attention on developing policies to support the sectors most vulnerable to climate variability. The response to this call by member states has been varied. In particular, in Italy the response is complex and extended over time in some phases.

This path started in 2012, when the ministry of environment and protection of territory and sea undertook a process of acquiring the most appropriate scientific knowledge on the subject; this evolved into the national strategy for adaptation to climate change in 2015. This document identifies specific principles and measures and aims to reduce the impacts and risks of climate change, protecting health, assets, and natural heritage.

The instrument for implementing the strategy is the national plan for adaptation to climate change, the definition of which was started in 2015. The plan is accompanied by two policy documents providing specific methodologies for the definition of regional and local climate change adaptation strategies and plans; it understands that local governments, together with regional ones, are the main promoters in similar resilience paths. The plan also supports coordination between different levels of government and the integration of adaptation principles and actions into local instruments. It considers, on the local scale, in addition to municipal adaptation plans, other tools that can contribute to the theme of climate adaptation in a transversal way. They are plans and strategies that consider climate resilience; the sustainable energy and climate action plans; the urban agenda programs that promote the path towards sustainable development; plans for sustainable urban mobility; plans and strategies for urban greening; strategic plans and municipal “climate-proof” building regulations. Therefore, in order to achieve the goal of adaptation, all methods, approaches, and pathways that support the implementation of adaptive actions in global and local territories are significant.

The European Union has assessed the efforts undertaken by member states, the results of which are contained in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Indeed, in order to ensure an effective response to the climate challenges, it is essential that the territories react through strategies and adaptation plans. However, current Italian legislation does not provide national laws that oblige municipalities to develop any type of plan or strategy aimed at reducing greenhouse gases or adapting cities to climate change (Pietrapertosa et al., 2019). In general, the actual provision of such tools is insufficient at the local level.

Therefore, it is particularly important to support spatial planners in defining appropriate climate change adaptation actions (Pietrapertosa et al., 2019), including theoretical and experimental research activities such as those carried out by the authors through a systematic literature review (SLR) process. In fact, such results can support spatial planners called to analyze the consequences of climate change; they translate climate data into the most effective configurations to support local decision-making.

DESIGN AND RESEARCH METHODS

Background

The research is based on the results of an analysis conducted through a SLR process on the four climate change risk categories identified by the intergovernmental panel on climate change. The four categories of risk included are the heat wave risk, the risk to agricultural production, the risk of water scarcity, and the flood risk. For the purposes of the review, literature selection criteria were defined. The first type of criteria is temporal and concerns the date of publication. In particular, the document search is limited to publications between 2013 and 2023. Furthermore, publications in journals were included. The analysis of Palermo and Chieffallo (2024) confirmed the relevance and spread of the four categories of risk mentioned above; they provided some useful reference guidelines to be drawn up in order to guide the research activities covered by this work.

In particular, the SLR’s results confirm the existence of complex interconnections between the different risk categories related to climate variability and the presence of more or less strong correlations with environmental characteristics, economic and social factors associated with urban, rural and coastal areas. In particular, heat wave risks need to be

considered in urban areas (Dong et al., 2020; He et al., 2020); risks to agricultural production and water scarcity in rural areas (Hansen et al., 2019; Komarek et al., 2020; Singh et al., 2018; Tzanakakis et al., 2020), and flood risks in coastal areas (Apollonio et al., 2020; Vousdoukas et al., 2018). This result is therefore the starting point for defining the research product, which must consider the risk categories and the territorial contexts according to their vocations.

Considering the SLR's results, with reference to urban areas, it is evident that the consequences of climate change are closely linked to levels of local vulnerability. Urban heat islands (Irfeey et al., 2023; Qiu et al., 2023; Rajagopal et al., 2023) is the phenomenon of higher temperatures in urban areas compared to surrounding areas. Heat waves are extreme weather conditions that occur in the summer season (Perkins-Kirkpatrick & Gibson, 2017; Muthers et al., 2017). The effects of rising temperatures can vary greatly depending on the physical, environmental, social, and economic characteristics of the site of interest (Li et al., 2023). Consider, for example, the benefits of tree-lined avenues, parks, and gardens.

Although the transition to new economies with less dependence on agricultural activities and a diversified economy have been supported internationally, the agriculture continues to be the driving force behind the economy of rural areas. Agricultural activities are strongly affected by climate change (Mutengwa et al., 2023; Omotoso et al., 2023; Rusmayandi et al., 2023). Raising awareness on this issue could help farmers adopt better management solutions (Vergamini et al., 2024), discouraging the processes of degradation, degeneration, and desertification (AbdelRahman, 2023; McKinley et al., 2017).

For coastal areas, climate change causes rising sea levels and more floods (Chen et al., 2023; Laino & Iglesias, 2023; Xu et al., 2023). In addition, account must be taken of phenomena such as the increase of salt water in rivers and changes in the functions of coastal ecosystems (Miah et al., 2023; Sahavacharin et al., 2022). The solution to these problems can be found in improved planning. In this context, it is necessary to identify best practices within the overall and integrated framework of institutional competences and to assess the expected impacts and eligible interventions to foster appropriate integration between the necessary sectors of activity and policies that focus on a complex system such as the coastal one (Gallina et al., 2020; Toimil et al., 2020).

Methodological Framework

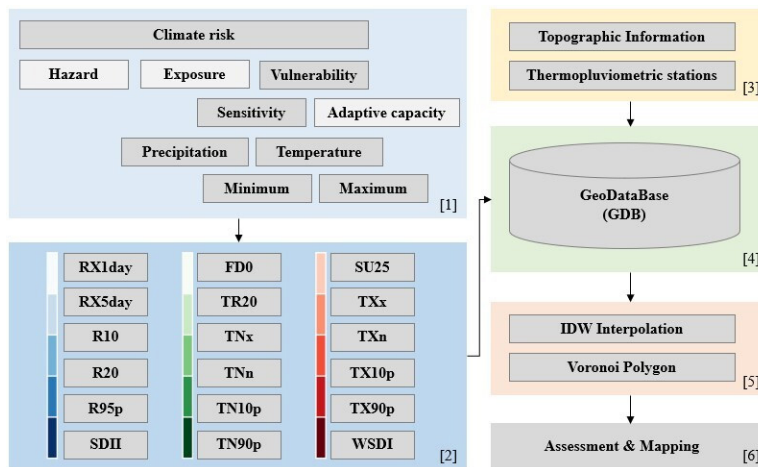
The definition of different climate risk scenarios in urban, rural, and coastal areas implies the need to integrate "ordinary" knowledge frameworks (Berke & Stevens, 2016). Recent digital technologies and information systems represent a useful tool for managing and exploiting these essential spatial data. This reflection has influenced the methodological choices leading to the definition of project outputs. The GDB assess local risk domains to climate change and develop the related risk maps. It must take into account the physical, environmental, and socio-economic variables (Yando et al., 2021). Therefore, the resulting planning actions contain proposals for solutions to identify adaptive measures. In regards to the physical and environmental specificities, the analysis of the state-of-the-art (Bardossy & Van Mierlo, 2000; Flannigan et al., 2016; Irwandi et al., 2023; Portmann et al., 2009; Rana et al., 2017; Vilorio et al., 2023; Zhang et al., 2023) has made it possible to identify the most representative and widely used climate parameters, which feed the GDB.

This research adopts an integrated approach aimed at the qualitative-quantitative characterization of local climate risk conditions; it implements the GDB. The purpose is to develop climate risk domains and the resulting digital mapping in a geographic information system (GIS) environments using quantum GIS (QGIS).

The GIS is a computer-based tool that allows one to perform spatial analysis through the digital representation of a geographical areas; it combines information of an alphanumeric type. Although the use of this technology has recently been favored by the proliferation of specific applications and georeferenced data, the literature (Bitelli et al., 2017; Resch et al., 2020) shows that, especially in the Italian context, application results are not always satisfactory. The creation of a GDB for planning

purposes requires the integration of other knowledge types in order to facilitate the conception and definition of application contents. The use of geo-statistical techniques for spatial interpolation is also an important element. As already mentioned, the relevance of the project for the development of innovative digital infrastructures and services is demonstrated by the desire to design and implement a GDB that responds to practical operational needs of planning based on knowledge and expertise gained about climate change. To this end, the proposed framework is composed of six steps, as seen in Figure 1.

Figure 1. Flowchart of the proposed framework and organization of data flows



Note. *RX1day* = highest one-day precipitation amount; *RX5day* = highest five-day precipitation amount; *R10* = heavy precipitation days; *R20* = very heavy precipitation days; *R95p* = total precipitation due to very wet days; *SDII* = simple daily intensity index; *FD0* = frost days; *TR20* = tropical nights; *TNx* = maximum value of daily minimum temperature; *TNn* = minimum value of daily minimum temperature; *TN10p* = cold nights; *TN90p* = warm nights; *SU25* = summer days; *TXx* = maximum value of daily maximum temperature; *TXn* = minimum value of daily maximum temperature; *TX10p* = cold days; *TX90p* = hot days; *WSDI* = *XX*; *IDW* = warm-spell duration index.

Step one is used for climate risk characterization. Specifically, according to the literature (Jurgilevich et al., 2017), climate change risk is a function of three parameters: hazard, exposure, and vulnerability. The three parameters may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making. In particular, hazard is the potential occurrence of a natural or human-induced physical event that may cause loss of life, injury, or other health impacts. Exposure refers to the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected. Vulnerability is the propensity to be adversely affected by climatic variability, and it is a function of sensitivity and adaptive capacity. As already mentioned, from an urban point of view, the research focuses on the first component, which expresses the degree to which the territorial system is influenced by the variability of climate changes. Finally, adaptive capacity is the combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts.

Step two includes the statistical modeling of precipitation extreme indices (Palermo et al., 2024). These indices are used to quantify the variations of data extremes, which are also very useful to policy makers.

Specifically, reference is made to the 18 indices provided by the expert CCI/CLIVAR/JCOMM team on climate change detection and indices; they are identified as being representative of the Italian climate. The above indices reflect climate change variability and trends (Guo et al., 2023). They are distinguished in precipitation extremes indices and minimum and maximum temperature indices.

Precipitation extremes indices are the highest one-day precipitation amount (RX1day - mm), the highest five-day precipitation amount (RX5day - mm), the heavy precipitation days (R10 - days), the very heavy precipitation days (R20 - days), the total precipitation due to very wet days (R95p - mm), the simple daily intensity index (SDII - mm/day).

Minimum and maximum temperature extreme indices are the number of frost days (FDO - days), the number of tropical nights (TR20 - days), the maximum value of daily minimum temperature (TNx - °C), the minimum value of daily minimum temperature (TNn - °C), the percentage of cold nights (TN10p - %), the percentage of warm nights (TN90p - %), the number summer days (SU25 - days), the maximum value of daily maximum temperature (TXx - °C), the minimum value of daily maximum temperature (TXn - °C), the percentage of cold days (TX10p - %), the percentage of hot days (TX90p - %) and the warm-spell duration index (WSDI - days).

Specifically, in order to clarify the statistical modeling operations carried out on the relevant series, the following is made explicit.

For daily rainfall series, the conventional approach is to consider heavy daily precipitation if it is greater than 10 mm and very heavy daily precipitation if it is greater than 20 mm. The days with heavy rainfall are marked by daily precipitation above the value corresponding to the 95th percentile of the series. The simple daily intensity index is the ratio of total annual precipitation to the number of rainy days in the year.

As regards the daily minimum temperature series, on frost days the minimum temperature is below 0°C, on tropical nights the minimum temperature is above 20°C, on cold nights the minimum temperature is below the value corresponding to the 10th percentile of the series, and on hot nights the minimum temperature is above the value corresponding to the 90th percentile of the series.

The daily series of maximum temperatures shows a maximum temperature above 25°C on summer days and below the 10th percentile on cold days. On hot days, the maximum temperature is higher than the value corresponding to the 90th percentile of the series. During hot periods, by convention, a maximum temperature above the value corresponding to the 90th percentile of the series is recorded for at least six consecutive days.

Step three consists of acquiring spatial information related to the study area and the location of thermo-pluviometric stations. This last aspect concerns the digitalization of the sites where the measurement instruments that allow to monitor the physical conditions of the atmosphere.

Step four represents the actual implementation of the GDB that receives the input data sets related to steps two and three. The term GDB suggests having all GIS data stored uniformly in a central location for easy access and management. In fact, this GDB helps in the storing of GIS attributes and spatial data.

Step five is about applying specific interpolation techniques, including the Inverse distance weighting (IDW) interpolation and Voronoi polygon, which estimates the relative values at non-sampled points starting from the known indices' values. The choice of interpolation technique depends on the objectives of the research. In the case of small study areas with few thermos-pluviometric stations, it is preferable to apply the IDW interpolation method to obtain a more accurate result. If one wants to have a general distribution of specific parameters in wider contexts, the Voronoi polygon algorithm may be sufficient.

In particular, the IDW interpolation algorithm assumes that a non-sampled point is more affected by nearby control points than by distant ones. According to Lu and Wong (2008), the IDW method is used to estimate the unknown value $\hat{y}(S_0)$ in position S_0 , given the y values observed in the sampled position S_p , as shown in Eq. (1):

$$\hat{y}(S_0) = \sum_{i=1}^n \lambda_i y(S_i) \quad (1)$$

In essence, the estimated value in S_0 is a linear combination of the weight (λ_i) and value y observed in S_i , where λ_i is often defined as Eq. (2):

$$\lambda_i = \frac{d_{0i}^{-\alpha}}{\sum_{i=1}^n d_{0i}^{-\alpha}} \quad (2)$$

This is shown, too, in Eq. (3):

$$\sum_{i=1}^n \lambda_i = 1 \quad (3)$$

The Voronoi polygon algorithm, on the other hand, generates convex polygons from individual points, dividing the plan into areas so that the generating points are closer to their polygonal points. Therefore, according to Bosisio et al. (2022), considering n sites s_1, s_2, \dots, s_n in a distant space (P, d), the algorithm partitionates P into regions S_1, S_2, \dots, S_n , as shown in Eq. (4):

$$S_i = \{p \in P \mid d(p, s_i) < d(p, s_j), i \neq j\} \quad (4)$$

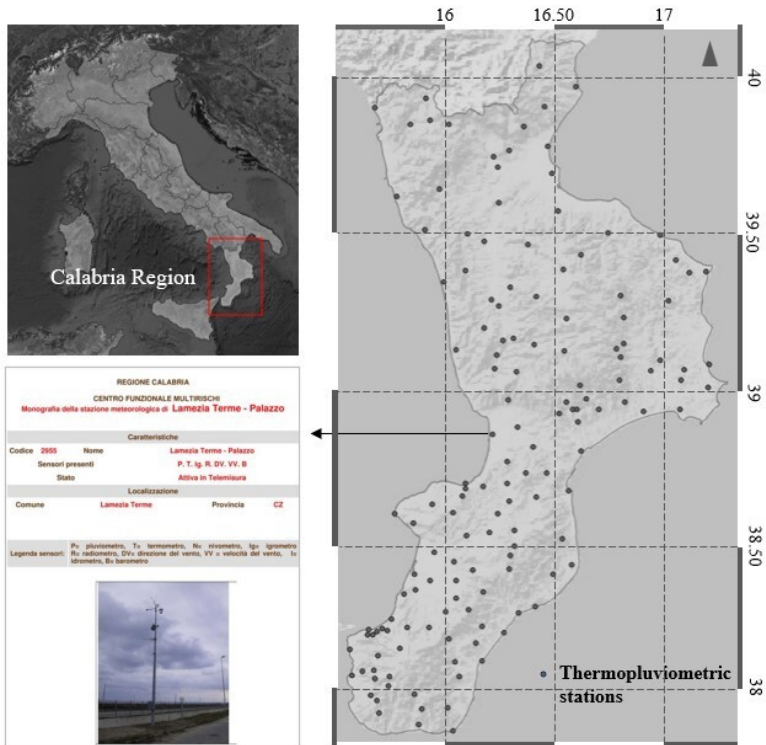
Finally, step six allows different possibilities for the visualization of the results obtained.

RESULTS

In order to illustrate the contents and potential of the framework developed for the planning of appropriate adaptive interventions, the main results obtained for the regional context of Calabria are presented below.

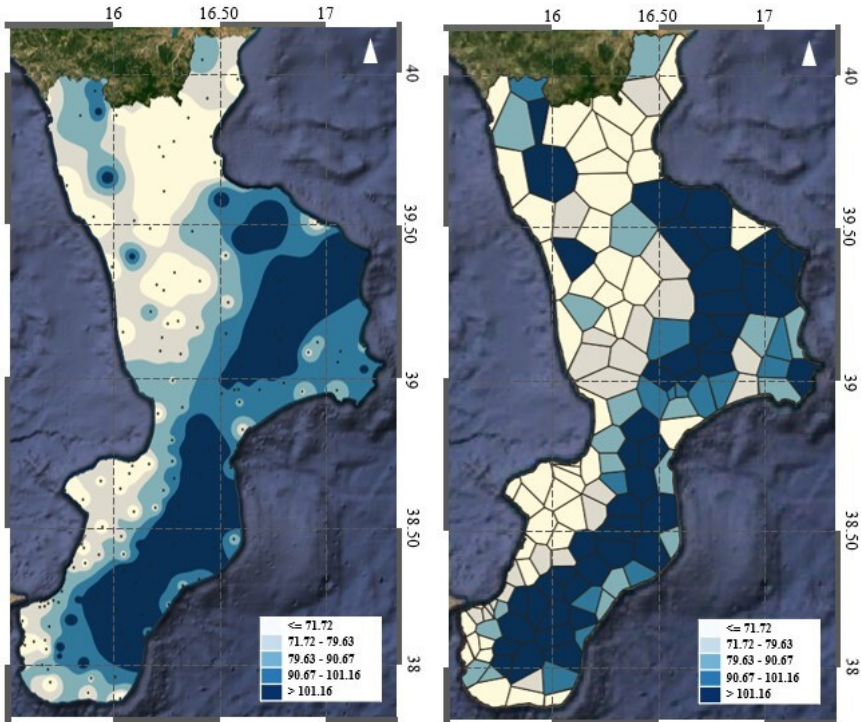
In step one, daily climate data for precipitation and minimum and maximum temperatures were considered for the 10-year reference period from 2013 to 2023, as recorded by 146 thermo-pluviometric stations, as seen in Figure 2.

Figure 2. Localization of thermo-pluviometric stations



Subsequently, for each station considered and for each year included in the period 2013-2023, the statistical modeling of the data was carried out to obtain the 18 summary indices. These data were then processed using both the more precise IDW interpolation method and the more immediate Voronoi polygon algorithm, as seen in Figure 3, to produce relevant climate maps.

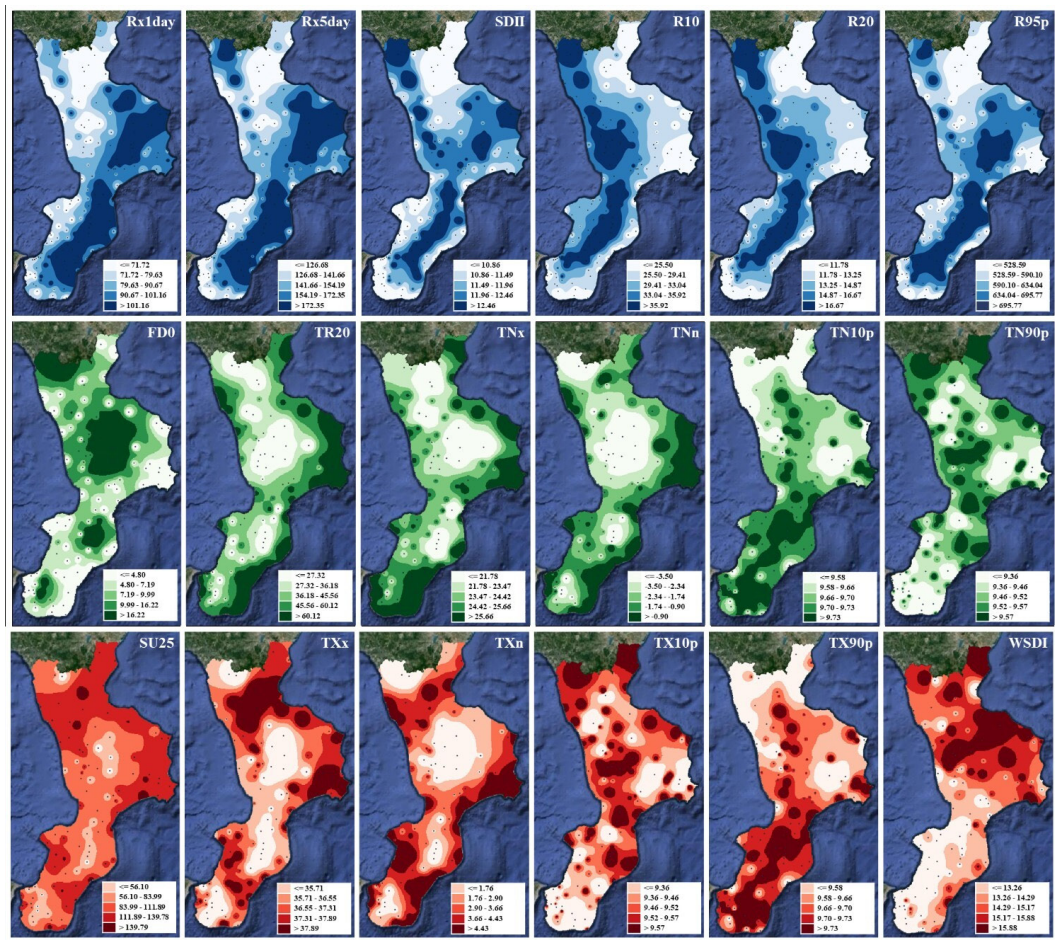
Figure 3. Comparison between interpolation methods



The implementation of the GDB offers several possibilities for analysis to create a network of interpolated nodes and to cover all points of the territory. For example, Figure 4 shows the outputs of the 18 indices for the average values recorded over the reference time period.

These results show that the Calabria region has peculiar microclimatic characteristics. Based on a visual analysis, the meteorological phenomena are strongly linked to geographical locations as well as geomorphological characteristics. The regional context is characterized by a complex topography and special physiographic characteristics that generate a wide variety of microclimates. The climate of Calabria is influenced by the presence of the sea and mountain areas. The Mediterranean climate is typical of coastal areas.

Figure 4. Average values for the period 2013-2023 for the 18 synthetic indices



Note. *RX1day* = highest one-day precipitation amount; *RX5day* = highest five-day precipitation amount; *R10* = heavy precipitation days; *R20* = very heavy precipitation days; *R95p* = total precipitation due to very wet days; *SDII* = simple daily intensity index; *FD0* = frost days; *TR20* = tropical nights; *TNx* = maximum value of daily minimum temperature; *TNn* = minimum value of daily minimum temperature; *TN10p* = cold nights; *TN90p* = warm nights; *SU25* = summer days; *TXx* = maximum value of daily maximum temperature; *TXn* = minimum value of daily maximum temperature; *TX10p* = cold days; *TX90p* = hot days; *WSDI* = *XX*; *IDW* = warm-spell duration index.

According to Palermo et al. (2024), with regard to extreme precipitation events, the analysis showed that although precipitations are more frequent on the western side of the region, these events are more intense on the eastern side.

In particular, maps related to *RX1day* and *RX5day*, to *SDII* and *R95p*, and to *R10* and *R20* have similar patterns. These deductions are confirmed by the analysis of the indices. In fact, in the decade 2014-2023, the average value of *RX1day* was 123.2 mm with a maximum of 393.0 mm recorded in 2016; the average value of *RX5day* was 223.1 mm with a maximum of 746.4 mm recorded in 2015; the average value of *SDII* was 14.0 mm/days with a maximum of 26.9 mm/days recorded in 2015; the average value of *R95p* was 774.2 mm with a maximum of 2010.8 mm recorded in 2015; the average

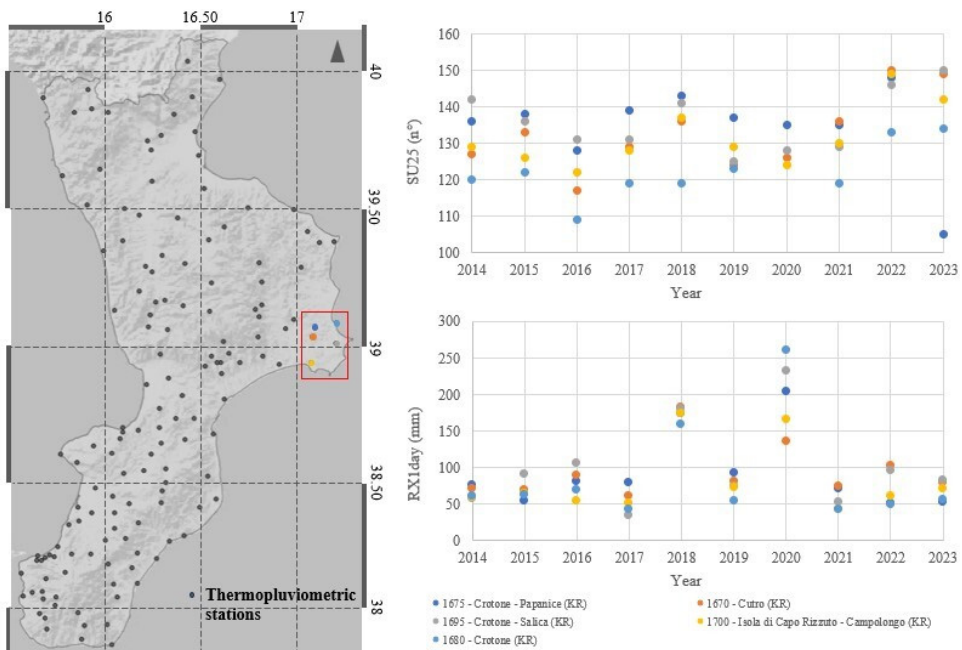
value of R10 was 38.2 days with a maximum of 63 days recorded in 2016; and the average value of R20 was 19 days with a maximum of 42 days recorded in 2021.

Regarding the temperature extremes, the analysis showed an increase in the average values over the reference period, especially in some areas located in Cosenza and Reggio Calabria.

In particular, maps related to TR20, TNx and TNn, and TN10p and TN90p have similar patterns. Likewise, maps related to TXx and TXn are analogous. As with precipitation, these deductions are also confirmed by the analysis of the indices. Indeed, in the decade 2014-2023, the average value of TR20 was 58.5 days with a maximum of 135 days recorded in 2023; the average value of TNx was 27.1 °C with a maximum of 34.3 °C recorded in 2023; and the average value of TNn was 0.3 °C with a minimum of -17.6 °C recorded in 2017. The average values of TN10p and TN90p were 9.9% without showing extremes. Finally, the average value of TXx was 36.6 °C with a maximum of 46.9 °C recorded in 2023, and the average value of TXn was 3.3 °C with a minimum of -13.8 °C recorded in 2017.

In addition to these general considerations, it is important to highlight that the GDB makes possible further analyses at different scales of intervention, such as those summarized in Figure 5; it is also important to conduct and repeat detailed studies within the same or different seasons in different years. In this sense, the GDB responds to the needs of an information structure to support planners in facilitating the acquisition and processing of data.

Figure 5. Localized analysis of some of the synthetic indices



Note. KR = Province of Crotona; RX1day = highest one-day precipitation amount; SU25 = summer days.

DISCUSSION AND CONCLUSIONS

This research is based on the need to address the climate crisis by planning joint mitigation and adaptation actions (Grafakos et al., 2020; Sharifi, 2021). The authors give an

operational guidance to the planning framework by making climate policies a priority public interest, also involving the institutional bodies with functions of territorial government and providing them a support in defining specific measures to align with national and European targets. Specifically, the importance of this research is supported by the critical issues that emerged. Planners are called upon to find solutions to the uncertain, sudden and geographically differentiated impacts produced by the interaction between territory and abnormal climatic characteristics. Therefore, within the framework of territorial government, it is necessary to structure information management systems so they are able to coordinate the complex set of data used for building digital, integrated, and shared knowledge frameworks.

The general aim of this framework is to encourage a new reading of the most current climatic dynamics, suggesting possible elements of innovation in this regard. In particular, the framework aims to provide concrete elements of support to the technical offices of local administrations as well as to professionals. Considering the Italian case, a possible application of the framework concerns feeding into specific tools to support climate adaptation planning.

In this regard, the results presented in Figure 4 are a good knowledge base, showing a specific subdivision within sensitivity classes on the territory. From a general point of view, the results confirm that the Mediterranean area is a hotspot for climate change; they highlight the importance of conducting in-depth analyses of thermo-pluviometric data in order to classify the territory on the basis of extreme events and according to Scherer et al. (1999). In addition, the maps in Figure 4 are of interest for planning purposes because putting them in connection with the parameters that influence adaptive capacity provides a measure of local vulnerability.

In addition, the analysis in Figure 5 allows one to see how in a confined area like the Crotona area, the indices are varied in time and space. In particular, the number of summer days is increasing on average, while the data relating to the highest one-day precipitation amount show a relatively constant trend, except for significant flood rains recorded in 2020.

Considering the only component of sensitivity, elaborating on objective and easily interpretable maps could also favor the necessary initiatives of “coproduction” (Satorras et al., 2020) or the adoption of a participatory approach (Tyler & Moench, 2012). This involves both institutions and the community in a converging learning process that includes knowledge sharing and discussion on alternative adaptation measures. The focus on participatory planning processes is also confirmed in the literature (Cradock-Henry et al., 2020; Galende-Sánchez & Sorman, 2021; Meerow & Woodruff, 2020); the activation of similar processes contributes to the achievement of “climate justice.” In particular, to this end, the prospects of e-participation are interesting, the benefits of which include securing an efficient means of data collection, faster public engagement, and removed physical barriers (Boureggh et al., 2023).

In conclusion, climate adaptation underlies the comparison with a future not always predictable, which makes it necessary to rethink traditional tools of analysis and urban planning. In this regard, a study of the differences of climate-related effects in urban, rural, and coastal areas was necessary. These factors create particular microclimates, or specific physical, chemical, and biological phenomena, determined by the interaction between built environments and climatic-environmental elements.

Based on the above considerations, the activities related to this research project are based on the assessment of climate sensitivity that focuses on the macro-regional territory and will evolve in a more detailed mapping for an urban pilot case. For this pilot case, the authors intend to draw up a climate action plan, also involving local communities. In this regard, the adoption of e-participation techniques (e.g. questionnaire, interview) will help to understand which are the best adaptive solutions at local level. To this end, the intuitive visualizations will promote educational, participatory, and training processes, increasing awareness in the population. Therefore, the GDB can be used as a tool in participatory planning, and it provides the means for more informed and place-specific urban planning outcomes. Specifically, the pilot case was identified in Catanzaro with the aim of investigating a heterogeneous context representative of urban, rural, and coastal areas.

COMPETING INTERESTS STATEMENT

The authors of this publication declare there are no competing interests.

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