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Special Issue 1.2021

The Emergency Plan for the use and management of the territory

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THE EMERGENCY PLAN FOR THE USE AND MANAGEMENT OF THE TERRITORY

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The cover image is a photo of the landslide that hit the municipality of Amalfi (Italy) in February 2021.

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Climate change as stressor in rural areas

Vulnerability assessment on the agricultural sector

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Abstract

This research aims at identifying main risk factors on rural areas, investigating characteristics both of the stressor and of the system, providing ordinary planning with tools that are useful in a preventive perspective and not only in emergency conditions. Local vulnerability assessment is a key tool able to provide a framework for prioritizing choices and actions in different strategies and policies. In literature, many studies focus on the assessment of local vulnerability, but there are few directly site-specific methods concerning climate change as stressor in rural areas, although they are particularly vulnerable contexts to climate change. Vulnerability of rural areas is principally linked to their significant dependence on agriculture sector and to specific socio-economic dynamics, often responsible of inequalities within communities.
Starting from these assumptions, authors define a methodology to quantitatively assess, in rural areas, the level of vulnerability to climate change based on climatic and context analysis at the municipality scale. The methodology is based on numerical and statistical computation operations on a set of indices of climate exposure, sensitivity and adaptive capacity in order to provide an aggregate Vulnerability Index. The paper presents the results of the application to the Calabrian territorial context of the Grecanica Area (Italy).

Keywords

Climate change; Vulnerability; Rural areas; Agricultural sector.

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1. Introduction

Urban planning is called to face multiple risks: they range from natural hazard-induced disasters to socio-economic crisis (Renn at al., 2018). In the last decades national and supranational governments are adopting tools and strategies able to manage an unexpected emergency and, only more recently, aiming at mitigating negative effects of an event through a preventive planning. But often, these policy instruments follow separate approaches and never interface each other, with an even more insidious problem: they have no adequate join with ordinary tools responsible to territorial transformations.

With special refer to Italian case, Emergency Plan is already considered as just an operational and rescue management tool that, in most cases, doesn't provide appropriate assessments regarding preventive strategies of risk mitigation. It could be considered inadequate for elaborating vulnerability, hazard, and exposure maps[1], because it merely transposes the indications of higher-level tools without an appropriate change of scale which, with more detailed assessments, would probably allow to reach different conclusions. The coordination among sector tools and ordinary planning, where present, is often unidirectional or limited to binding character: the Hydrogeological Plan, for example, identifies areas at risk with the only main objective to establish precise limitations in land use; other specialist reports (such as geological ones) born as support of ordinary plans, remain still today a separate part of the overall planning process (Menoni, 2006). It is also important to point out that the Emergency Plan doesn't consider directly risks related to climate change. In the European context, on the other hand, the Sustainable Energy and Climate Action Plan (SECAP) contains specific references to the assessment of vulnerability to climate change considering different types of risk (flood, landslide, erosion). The implementation of the SECAP favored by the Covenant of Mayors for Climate and Energy sees European cities committed to reducing their CO2 emissions and increasing urban resilience by adapting to the effects of climate change.

Moreover, it's worth to specify that the variety of risks is not only linked to their typology, but also to their spatial and temporal dimensions. With reference to first aspect, every risk mitigation strategy should be implemented from a site-specific knowledge framework, able to identify both the scale of application and the characteristics of the area where a type of risk acts. From a temporal point of view, effective mitigation strategies should take into account the not-ordinary nature of disasters, but also how the natural evolution of the territory affects the ordinary dimension. Just think of those phenomena that generate slow but linear (and often disruptive) changes on the territory that Brunetta & Salata (2019) identify, for example, in land consumption, erosion and, especially, in climate change.

Starting from these assumptions and following a site-specific view, this research aims at identifying main risk factors on rural areas, investigating characteristics both of the stressor and of the system, providing ordinary planning with tools that are useful in a preventive perspective and not only in emergency conditions. Rural areas are characterized by their social, economic and environmental diversity. Frequently they suffer from the

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[1] The definitions of vulnerability, hazard, exposure, and risk to which we will refer in this paper are the following (Pachauri et al., 2014):

- Vulnerability: the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt;
- Hazard: the potential occurrence of a natural or human-induced physical event or trend or physical impact 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. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts;
- Exposure: the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected;
- Risk: the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure.

social point of view of rural exodus and the aging of the population, from the economic point of view of a high rate of poverty and from dependence on agriculture as the main productive sector and from the environmental point of view of natural risks (geophysical, meteorological, hydrological and climatic). Pagliacci (2017), highlighting the link between rurality and periphery and between hydro-geological and seismic hazards in Italy, has shown that the areas with high landslide hazard in rural municipalities represent 85% of the total risk areas and that inland areas (the most peripheral Italian municipalities) are more exposed than the national average to landslides and seismic events in terms of surface and population. Furthermore, agricultural activity, can suffer the effects of catastrophic events more than other activities, given its dispersion over the territory (Pagliacci & Bertolini, 2016). With respect to this condition, it has been recognized (Yasuhara et al., 2015; Gasparri & Iraldo, 2020; Islam et al., 2020) how climate change increases direct risks such as floods, storms, droughts, and sea storms that are increasingly frequent and higher intensity. In order to address these issues, the development of rural policies should first of all incorporate the different specific characteristics of rural areas through a territorial and multisectoral approach.

Based on related works (Section 2), this paper proposes a methodology (Section 3) aimed at quantifying the municipal vulnerability to climate change focusing on the agricultural sector through a multidimensional approach that combines climatic and contextual factors (environmental and socio-economic) with respect to climatic exposure, sensitivity and adaptive capacity. The results of the application of the methodology on a territorial context of southern Italy (Section 4), intend to suggest useful considerations both to verify the integration of mitigation measures to climate change in planning and to evaluate which tools and strategies can increase the resilience of the territories (Section 5).

2. Related works

Climate change is a large-scale challenge (Papa et al., 2015) and the need to define consequential adaptation measures is internationally recognized (Zucaro & Morosini, 2018). This is confirmed by the adoption in 2015 of the Sendai Framework for Disaster Risk Reduction and the Paris Agreement on climate change which support national and supranational strategies in increasing coherence[2] in the approaches to Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) planning. OECD (2020) defines a set of opportunities for achieving greater coherence in CCA and DRR including put further emphasis on generating comprehensive information related to current vulnerability to make tailored climate information readily available to support "evidence-based" policies. In fact, the effects induced by the climate are diversified in local contexts according to the physical and natural condition, the socio-economic development and the adaptability that characterizes them and local instruments and policies do not always take them into account. Local vulnerability studies with focus on thematic areas oriented to priority evidence can reduce this gap strengthening their resilience (Galderisi & Ferrara, 2012). The thematic focus that will be explored is represented by the agricultural sector for rural areas. In fact, the agricultural sector suffers the effects of climate change in terms of productivity and food security (Caserini, 2015) due to frequent phenomena in southern Europe such as extreme heat waves and the reduction of rainfall and water resource (Kelemen et al., 2009). Increasing awareness of weather instability is essential in order not to run the risk, for example, that farmers adopt management solutions with a greater impact on less protected natural resources and abandoning areas more exposed to instability, favouring the processes of degradation and desertification (Calvitti et al., 2016).

The impacts of climate change can be broadly grouped under three headings: ecological, social, and economic. The ecological impacts of climate change include shifts of vegetation types and associated impacts on

[2] The advantages of greater coherence between the two policy approaches are manifold, especially in virtue of the close correlation among the effects of climate change and natural risks, which should be implemented in local development strategies and policies. However, to further guide decisions on CCA and DRR, climate data should be supplemented with information on other ecological, economic and social factors affecting local vulnerability.

biodiversity; change in forest density and agricultural production; expansion of arid land; decline in water quantity and quality; and stresses from pests, diseases, and wildfire. Salient social impacts may include changes in employment, equity, risk distribution, and human health, and relocations of populations. Economic impacts include increased risk and uncertainty of forest or agricultural production, alteration in productivity for crops and forest products, reduction in supply of ecosystem goods and services, increased cost of utilities and services, and altered energy needs (Alavalapati et al., 2011). These three headings of impacts assume particular relevance in rural areas. Thus, site-specific methods of assessment are required to assess the levels of vulnerability to human communities due to multiple driving forces in relation to specific outcomes (Adger & Vincent, 2005; Pandey & Jha, 2012). The vulnerability of agricultural sector to climate change varies according to exposure to adverse climatic conditions and the socio-economic context. In particular, socio-economic factors determining resilience are among other things: characteristics of farms, such as type of production, size and level of intensity; diversity of cultivation and livestock systems, presence of other sources of income external to agriculture; access to useful information, skills and knowledge of climate trends and adaptive solutions; the role played by advisory services in facilitating adaptation; general socio-economic situation, particular vulnerability of farmers with limited resources or established in particularly remote rural areas; access to available technologies and infrastructure capacity (Parker et al., 2019; Kantamaneni at al., 2020; Seif-Ennasr et al., 2020; Ju et al., 2020). The unequal effects of climate change could accentuate regional differences and exacerbate economic disparities. In the long term, climatic pressures could lead to further marginalization of agriculture or even the abandonment of agricultural land in certain parts of the Europe.

The literature provides many definitions of vulnerability describing its components and conceptual frameworks that give mining to the definition and can be analysed according to the analytical context in a transparent and repeatable way (Nelson et al., 2010). The Intergovernmental Panel on Climate Change (IPCC) describes vulnerability as "the degree of susceptibility or incapacity of a system to face the adverse effects on climate change" (Pachauri et al., 2014), also including variability and extreme events. It assumes that vulnerability is a function of three dimensions that are exposure of a system, its sensitivity and its adaptive capacity.

A commonly used quantitative approach is the construction of a vulnerability index starting from specific sets or combinations of indicators (Gbetibouo et al., 2010; Monterroso et al., 2014). In order to define the methodology, we analysed some studies proposed in the literature. Tab. 1 shows the main results.

These studies show how vulnerability is context-specific, and the factors that make a system vulnerable to the effects of climate change depend on the nature of the system and the type of effect in question (Brooks et al., 2005).

3. Methodology

This research is aimed at proposing a new methodology, based on an index approach, able to assess vulnerability to climate change in rural areas and to evaluate how the current strategies and policies treat this issue. This study follows the definition of vulnerability adopted by the IPCC (Pachauri et al., 2014). According to this definition, the research treats agricultural sector as the vulnerable system and climate change as the stressor (Wiréhn et al., 2015) through two different type of analyses:

- Climatic analysis, linked to the stressor and thus to the exposure of the system;
- Context analysis, linked to the characteristics of the system itself that, being specifically a rural area as anticipated, will deal with special refer to agricultural sector and to socio-economic features of the area.

The choice of combining analysis derives from some literature studies aimed at providing different interpretation of vulnerability: the outcome vulnerability, principally focused on information about potential climate impacts (exposure of a system) and the contextual vulnerability, rooted on internal characteristics of the vulnerable system or community that determine its propensity to harm for hazards (O'Brien et al., 2007; Füssel, 2010).

If researchers and administrators didn't act to properly combine these two different approaches they, taken individually, could produce very different ranking of vulnerable regions and tend to choose or technological solutions to minimize particular impacts or the reliance exclusively on response capacity of a community. This strict choice could affect system worse than vulnerability itself.

Study name	**Dimensions and Assessment outputs**
Assessment of composite index method for agricultural vulnerability to climate change (Wiréhn et al., 2015)	System of interest: Swedish agricultural productivity; Spatial scale: Municipal level Main biophysical aspects considered: temperature and precipitation information, crop diversification, erosion risk, soil characteristics; Main socio-economic aspects considered: population density, unemployment rate, social welfare payments, farm holding size and income; Methods and tools: Vulnerability index is based on standardisation of data and PCA to generate weights; Presentation of results: Use of narratives, maps, tables.
Vulnerability of the South African farming sector to climate change and variability: An indicator approach (Gbetibouo et al., 2010)	System of interest: South African farming sector; Spatial scale: Provincial level; Main biophysical aspects considered: frequency of past climate extremes, predicted change in temperature and rainfall, irrigation rate, land degradation, crop diversification; Main socio-economic aspects considered: rural population density, social capital (literacy rate, HIV prevalence), human capital, financial capital (farm income, farm size, access to credit), physical capital (infrastructure); Methods and tools: Climate vulnerability indices are based on three different weightings and three different summarizing methods; Presentation of results: Use of narratives, maps, tables.
Two methods to assess vulnerability to climate change in the Mexican agricultural sector (Monterosso et al., 2014)	System of interest: Mexico's agricultural sector; Spatial scale: Municipal level; Main biophysical aspects considered: extreme events, environmental problems, climate, agriculture, natural capital; Main socio-economic aspects considered: human capital, social capital, financial capital; Methods and tools: Climate vulnerability indices are based on PCA and equal weights; Presentation of results: Use of narratives, maps, tables.
Climate vulnerability index – measure of climate change vulnerability to communities: a case of rural Lower Himalaa, India (Pandey & Jha, 2012)	System of interest: Vulnerability of rural communities in Himalaya; Spatial scale: District level; Main biophysical aspects considered: natural disaster and climate variability, health, food, water; Main socio-economic aspects considered: socio-demographic profile, livelihood strategies and social networks; Methods and tools: Aggregation of data undertaken from household questionnaire survey; Presentation of results: Use of narratives, tables and charts.
Vulnerability Assessment of Forest Fringe Villages of Madhya Pradesh, India for Planning Adaptation Strategies (Yadava & Sinha, 2020)	System of interest: Vulnerability of forest fringe villages of Madya Predesh, India; Spatial scale: District level; Main biophysical aspects considered: agriculture, energy, water access; Main socio-economic aspects considered: social class, economic class, level of education, occupation; Methods and tools: Aggregation through PRA of indicators chosen based on the review of the literature and a reconnaissance survey. Using of PCA for extraction the significant indicators and Varimax method for the rotation of the factors; Presentation of results: Use of narratives and tables.
Climate-drive vulnerability and risk perception: implications for climate change adaptation in rural Mexico (Michetti & Ghinoi, 2020)	System of interest: Vulnerability of rural communities located in Mexican lagoon; Spatial scale: Municipal level; Main biophysical aspects considered: identification of communities most affected by climate change according to micro-level statistics and census data; Main socio-economic aspects considered: working conditions, affiliation to cooperatives or other organized structures, family earnings, socio-political relations and beliefs, perceptions and knowledge; Methods and tools: Aggregation of data from results of structured survey; Presentation of results: Use of narratives, tables and charts.
The effect of spatial proximity to cities on rural vulnerability against flooding: an indicator-based approach (Jamshed et al., 2020)	System of interest: Vulnerability of rural farming communities against flood hazard in Pakistan; Spatial scale: Sub-district level; Main biophysical aspects considered: distance to water body, degree of loss/damage to standing crops, inadequate availability of water for farming, absence of safe drinking water; Main socio-economic aspects considered: physical dimension (distance to the nearest health facility, distance to paved road), human dimension (household head's education, Household accessing the market, weather and water-related information more frequently), social dimension (household living in the community, household accessing agriculture extension services more frequently), financial dimension (economic dependency ratio, household with more than one income source); Methods and tools: Aggregation of data from results of household survey through Mann-Whitney U and Pearson's correlation; Presentation of results: Use of narratives, tables and charts.

Tab.1 Review of related literature studies based on Carter & Mäkinen (2011) and Fellman (2012)

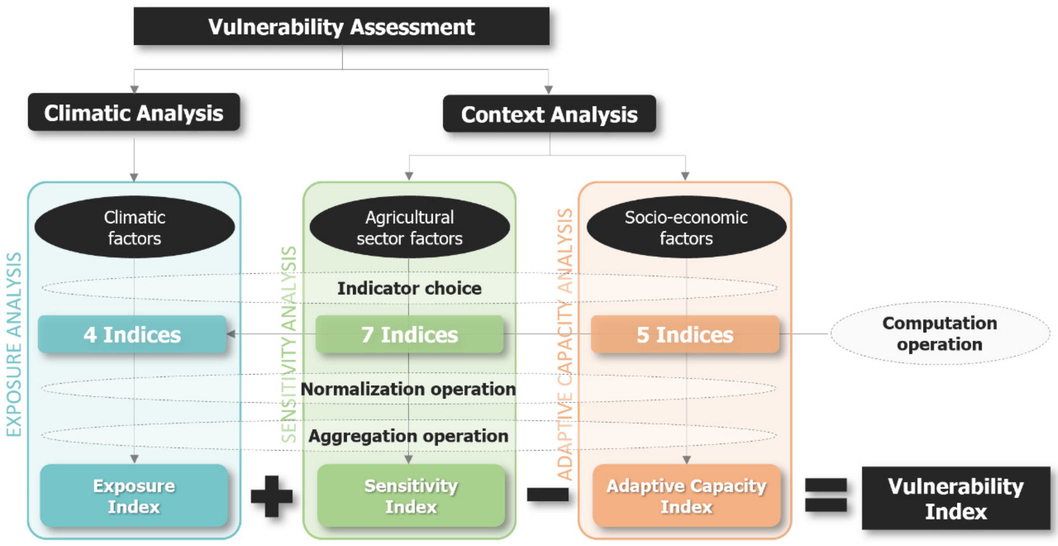

Fig.1 Methodology flow chart

The Fig.1 summarizes the methodology process that can be described into five steps:

- Index choice: a set of appropriate indices are chosen by the authors reworking and referring to the themes proposed by different literature studies in addition to those already provided in the previous section. Major details of this first methodological step will provide in following sub-paragraphs;
- Computation operation: each index is calculated at municipal scale through different procedures depending on whether is a climatic or context analysis. A geo-spatial database is populated trough a join algorithm among numerical and spatial data;
- Normalization operation: it is essential before any data aggregation to construct summary indices comparable both by each other – they often have different measurement units – and among single municipal results. This step is useful for understanding better the local vulnerability and its spatial distribution, for orienting policies toward a specific area or for identifying lands with urgent requirements. Currently, numerous methods of normalization exist (Freudenberg, 2003; Jacobs et al., 2004; Joint Research Centre-European Commission, 2008): for both analyses, the authors use min-max method that normalizes the measures to have an identical range (from 0 to 1) by subtracting the minimum value and dividing it by the range of the measured value.

$$x_{i,1} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (1)$$

  In formula (1) x_i is the individual data to be transformed, x_{min} the lowest value for that index, x_{max} the highest value for that index and $x_{i,1}$ the normalized value: for every index, the minimum value of that feature gets transformed into a 0, the maximum value gets transformed into a 1 and every other value gets transformed into a decimal between 0 and 1.

- Aggregation operation: for each dimension, a synthetic index has to be defined.

$$DI_j = \frac{\sum_{i=1}^{n_j} w_i \cdot x_{i,1}}{n_j} \quad (2)$$

  Formula (2) allows the calculation of DI_j, the synthetic index for dimension j, by combining the normalized value of the indices $x_{i,1}$ previously weighted by associating the relative weight w_i; n_j is the total number of chosen indices for dimension j. Authors assign an equal weight to every index and calculate three final indexes through an aggregation procedure based on an arithmetic average.

It's worth to specify that is very important to pay attention to the direction of the index values. As described in following sections, authors define for each index a functional relationship able to express the contribution of the single index to the assessment of the analysed dimension: a positive relationship increases the value of the synthetic index I_j, a negative one decreases it;

- Calculation of Vulnerability Index: the last step consists in valuing vulnerability. Following previous assumptions, it could be defined as vulnerability to climate change assessed on agricultural sector in rural areas. Vulnerability Index VI depends on Climatic and Context Analyses and, particularly, it is a function of the three synthetic indices of exposure (EI), sensitivity (SI) and adaptive capacity (ACI), as express by formula (3).

$$VI = f(Climate\ Analysis, Context\ Analysis) = EI + SI - ACI \quad (3)$$

Particularly, exposure and sensitivity positively affect vulnerability, while adapting capacity is considered as a mitigating factor with a negative impact on vulnerability (Liu et al., 2013; Murthy et al., 2015; Michetti & Ghinoi, 2020).
Following two sub-paragraphs will describe into details the implementation of the first step of methodology both for climatic and context analysis.

3.1 Climatic Analysis

The climatic analysis is a fundamental prerequisite for assessing the impacts of climate change. The methodology considers the information relating to temperatures (Clim-1 and Clim-2), rainfall (Clim-3), and the risk of desertification (Clim-4) in order to evaluate the variations by observing the climatic variables and applying statistical methods and models of recognition and estimation of ongoing trends.

Code	Name	Definition	Functional Relationship[3]
Clim-1	Synthetic index of extremes of cold	Arithmetic average of standardization values of FD0, TR20, TNx, TNn, TN10p, TN90p4	+
Clim-2	Synthetic index of extremes of heat	Aritmetic average of standardization values of SU25, TXx, TXn, TX10p, TX90p, WSDI5	+
Clim-3	Synthetic index of the extremes of precipitation	Arithmetic average of standardization values of RX1day, Rx5day, R10, R20, R95p, SDII6	+
Clim-4	Territory at desertification risk	Percentage of dry soil surface between 86-159 days	+

Tab.2 Climate exposure index

In Tab.2 the Clim-1, Clim-2, and Clim-3 indices are the result of the aggregation of the indices defined among the most representative of the Italian climate by the Italian National Institute for Environmental Protection and Research (Alexander et al., 2006). As stated by the Expert Team on Climate Change Detection and Indices (ETCCDI) of the "CCL / CLIVAR Working Group on Climate Change Detection" (Peterson et al., 2001), they are suitable to describe the extremes of temperature and precipitation in terms of frequency, intensity and duration. These indices are divided into different categories.

[3] It expresses the contribution of the single indicator to increase (+) or decrease (-) exposure dimension.
[4] Considered indicators are:frost days (FD0), tropical nights (TR20), maximum value of daily minimum temperature (TNx), minimum value of daily minimum temperature (TNn), cold nights (TN10p), warm nights (TN90p).
[5] Considered indicators are:summer days (SU25), maximum value of daily maximum temperature (TXx), minimum value of daily maximum temperature (TXn), cold days (TX10p), wam days (TX90p), warm spell duration indicator (WSDI).
[6] Considered indicators are:maximum 1-day precipitation amount (RX1day), maximum 5-day precipitation amount (Rx5day), number of heavy precipitation days (R10), number of heavy precipitation days (R20), very wet days (R95p), simple daily intensity index (SDII).

Some indices are defined by a fixed threshold value, others are absolute indices, others are based on percentiles, and still others express duration (Francini et al., 2020). The methodology is therefore based on the elaboration of the data of the historical series of the minimum temperatures, the maximum temperatures and the daily accumulated precipitation recorded by the stations equipped with thermometer and rain gauge present in the study area and from the external ones no more than 15 km from the internal ones. For each hydrological series, in order to characterize and quantify the ability to provide reliable information, the parameters of continuity, completeness and quality defined by Braca et. al (2013) were calculated.

The continuity parameter ($C1$) is defined (4) so that a series that presents all valid data, equal to the maximum number of data, has a continuity index equal to 1 while, a series that presents valid data alternating with a missing data and which therefore has the maximum value of missing data intervals having value 0.

$$C1 = 1 - 2 * \frac{number\ of\ missing\ data\ intervals}{maximum\ number\ of\ data} \tag{4}$$

The completeness parameter ($C2$) provides (5) an indication of the number of valid data contained in the series with respect to the maximum totality of the data between the first and last detected value.

$$C2 = \frac{numer\ of\ valid\ data}{maximum\ number\ of\ data} \tag{5}$$

The quality of the series was assessed using the $iQuaSI$ index (6) based on the length of the series expressed in years and on the quality class of the single data.

The index varies between 0 and 1 and is defined as a linear combination of the ratios between the length of the part of the series consisting of data of a given quality class and the total length, with coefficients dependent on the length of the series.

$$iQuaSI = a_L * \left(\frac{L_A}{L}\right) + b_L * \left(\frac{L_B}{L}\right) + c_L * \left(\frac{L_C}{L}\right) + d_L * \left(\frac{L_D}{L}\right) \tag{6}$$

The methodology considers only the series characterized by maximum continuity and completeness parameters ($C1 = 1; C2 = 1$), as well as to exclude the series considered unusable ($iQuaSI \leq 0{,}10$).

The average value of the indices with respect to the series of historical data considered usable was associated with each station.

The Voronoi polygons were then constructed and the values of the indices for each municipality quantified as an average weighted on the areas of the Voronoi polygons influencing the municipality. Considering the last index, several literature studies identify drought as a potential hazard due to climate change with large negative impacts on agricultural sector (Wilhelmi & Wilhite, 2002; Liu et al., 2013; Murthy et al., 2015).

Starting from indications of a report of the General Directorate for Sustainable Development, Climate and Energy of Italian Ministry of Environment and Land and Sea Protection (2012) and following general goals of European project Region 2020 "*An Assessment of Future Challenges for EU Regions*", authors propose index Clim-4 in order to evaluate the exposure of the system to desertification risk.

3.2 Context Analysis

As anticipated, context analysis includes evaluations both on sensitivity of agricultural sector and on socio-economic features of the community able to increase or decrease the adaptive capacity.

Sensitivity refers to the degree of system response due to climate change. It is also the degree to which a system is potentially modified by a disturbance: human and environmental conditions can improve or worsen the impacts (Monterroso et al., 2014).

The proposed methodology inserts in this dimension some municipal indices able to describe the current state of the agricultural sector (Agr-1, Agr-2, Agr-3, Agr-4) and population (Pop-1, Pop-2) exposed to climate change (Tab. 3) (Jamshed et al., 2020; Yadava & Sinha, 2020; Žurovec et al., 2017).

Code	Name	Definition	Functional Relationship[7]
Agr-1	Percentage of utilised agricultural land	Percentage ratio between utilised agricultural land and total agricultural land	+
Agr-2	Agricultural family labour force	Number of farmhouses with family labour force	+
Agr-3	Impact of employment in the agricultural sector	Percentage ratio between those employed in agriculture and the total number of employees	+
Agr-4	Crop diversification	Degree of subdivision of land into different crops	-
Agr-5	Percentage of surface in protected areas	Percentage ratio between municipal protected areas and total municipal area	+
Pop-1	Percentage of rural population	Number of population belonging to "rural cells" of grid defined by EUROSTAT	+
Pop-2	Demographic sensitivity index	Index function of population density, area of inhabited and productive localities and old-age index	+

Tab.3 Context Analysis: sensitivity indices

Agricultural Sector indices describe the current situation both of lands and agricultural employment, while Population indices assess the human sensitivity to climate-hazard exposure.

Almost all of proposed indices are directly available at municipal scale, normally through data provided by national statistics.

A short explanation is needed about the index Agr-4. Currently, crop diversification is universally recognized as a best practice to increase soil quality and productivity of a land (Lin, 2011; Mustafa et al., 2019; Piedra-Bonilla et al, 2020). For determination of index Agr-4 authors follow criteria established by a Special Report of Court of Auditors of 2017 "*Greening: a more complex income support scheme, not yet environmentally effective*"[8]. The report explains that crop diversification is guaranteed when: if arable land exceeding 30 hectares, it should host at least three crops (1st criterion); the share of arable land devoted to main crop is limited to 75% (2nd criterion); the two main crops taken together must not cover more than 95% of arable land (3rd criterion).

According to these disposition, Agr-4 is calculated as follow:

- if municipal utilized agricultural land doesn't respect 1st or 2nd criterion, Agr-4 is equal to 0;
- if municipal utilized agricultural land respects 1st and 2nd criterion, Agr-4 is calculated as in Formula (7).

$$Agr-4 = 100\% - (\%MC_1 + \%MC_2) \quad (7)$$

Where $\%MC_1$ and $\%MC_2$ are respectively the percentage of first and second main crops.

Adaptive capacity is similar to or closely related to a host of other commonly used concepts, including adaptability, coping ability, management capacity, stability, robustness, flexibility and resilience (Adger & Kelly, 1999; Jones, 2001; Füssel & Klein, 2006; Smit & Wandel, 2006). At the local level the ability to undertake adaptations can be influenced by such factors as social situation, level of literacy or employment, economic well-being, technological and information resource, infrastructure, the institutional environment and the political influence (Adger et al., 2001; Wisner et al., 2004). Indices chosen by authors (SocEco-1, SocEco-2, SocEco-3, SocEco-4, SocEco-5) are illustrated in Tab.4.

Also for the assessment of Adaptive Capacity, almost all indices are available at municipal scale into several national databases. All of them can be evaluated numerically, except for SocEco-4 that needs for a qualitative

7 It expresses the contribution of the single indicator to increase (+) or decrease (-) sensitivity dimension.

8 Available at https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_EN.pdf. [Accessed on 4 December 2020].

estimation based on the assessment of the presence of a municipal Emergency Plan and its level of updating, following criteria described below:

- Absence of an Emergency Plan, SocEco-4 = 0;
- Presence of a not-updated Emergency Plan, SocEco-4 = 0.33;
- Presence of an updated Emergency Plan (not digital), SocEco-4 = 0.66;
- Presence of an updated Emergency Plan (digital), SocEco-4 = 1.

Index Code	Name	Definition	Functional Relationship[9]
SocEco-1	Level of economic well-being	Income per capita	+
SocEco-2	Index of social unrest	Index function of 7 factors of social unrest[10]	-
SocEco-3	Level of educational opportunity	Number of schools	+
SocEco-4	Level of preparedness and response capacity	Presence of an updated Municipal Emergency Plan	+
SocEco-5	Level of quality of food and wine productions	Number of certified food and wine products	+

Tab.4 Context analysis: Adaptive capacity indices

4. Case study and results

The proposed methodology was tested on 11 municipalities (01-Bagaladi, 02-Bova, 03-Bruzzano Zeffirio, 04-Cardeto, 05-Ferruzzano, 06-Montebello Jonico, 07-Palizzi, 08-Roccaforte del Greco, 09-Roghudi, 10-San Lorenzo, 11-Staiti) belonged to Grecanica Area, a territorial context located in southern Calabria, Italy. Grecanica Area is considered of particular national interest not only because it is a rural area (according by EUROSTAT (2011) classification) strongly suited to agriculture sector, but above all because it is one of 72 Pilot Areas by Italian National Strategy of Inner Area[11] and was interested in European LEADER program 2014-2020. On a total area of 434.80 km^2, San Lorenzo is the municipality with the largest extension (64.50 km^2), while the smallest one is Staiti (16.30 km^2). Fig. 2 shows the main characteristics of the study area, in terms of morphological conditions, location of areas exposed at hydrogeological risks and the evolution of demographic situation in the last 30 years.

This last aspect deserves a little specification because it is at the same time the cause and the effect of many socio-economic dynamics. The depopulation of the inner towns and villages began in the 60s of the last century with emigration to the Northern Italy and abroad or to the coast and the city of Reggio Calabria. Following classification offered by Lanzani e Zanfi (2019), authors proposes the demographic trend map of Fig. 2 dividing study area in three classes, associating the first letter of alphabetical string of the map legend to the period 1991-2001, the second to 2001-2011, the third to 2011-2019, according to the following code: D= demographic decrease, S=demographic stability, G=demographic growth. Almost all municipalities of study area present a persistent decrease of population, except for Palizzi and Ferruzzano that today have a

[9] It expresses the contribution of the single indicator to increase (+) or decrease (-) adaptive capacity dimension.

[10] Considered factors are: percentage of population aged between 25 and 64 who are illiterate and literate without a qualification; percentage of households with 6 and more members; percentage of young single-parent families on the total of families; percentage of families of only elderly people (65 years and over) with at least a member over eighty; percentage of population in conditions of severe crowding; percentage of NEET (young people (15-29 years) Not in Education, Employment or Training); percentage of families with children in which no one is employed.

[11] SNAI, 2014, Strategia Nazionale per le Aree Interne: definizione, obiettivi, strumenti e governance. Available at: https://www.miur.gov.it/documents/20182/890263/strategia_nazionale_aree_interne.pdf/d10fc111-65c0-4acd-b253-63efae626b19 [Accessed on 11 December 2020].

demographic stability after a long period of decrease and Montebello Jonico with a slight reversal of a negative demographic trend.

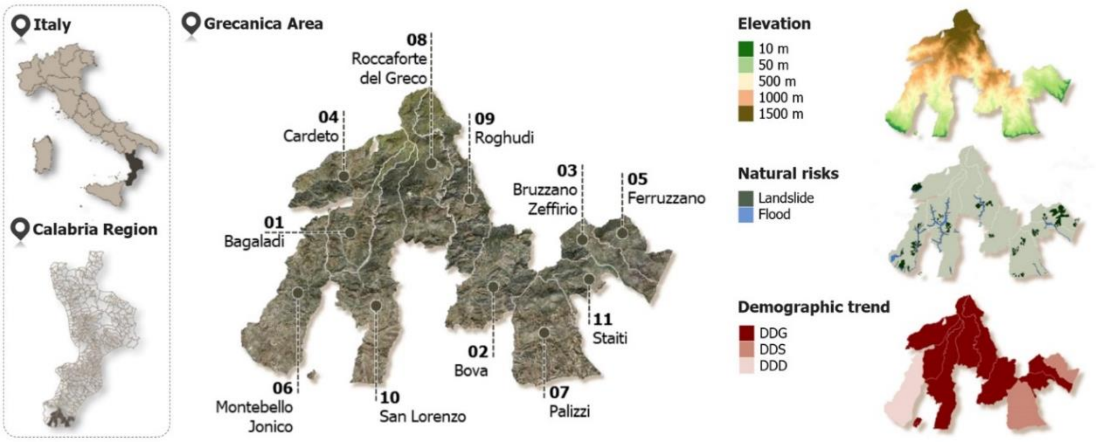

Fig.2 Study area

The effect of depopulation emerges from the high number of unoccupied housing stock (ISTAT, 2011) – that represents a serious danger in case of earthquake (Calabria is the one of the Italian regions with the highest seismic risk) – but also from the state of neglect of many lands, once utilized and that represented a great resource both for agricultural sector and the whole local economy, strongly affected by climate change too.

4.1 Grecanica Area: climatic analysis

In order to define the indices in accordance with the proposed methodology, we have identified the stations equipped with thermometer and rain gauge located in the study area and in the buffer zone. We evaluated each series recorded by the stations through the parameters of continuity, completeness and quality and excluded the stations that did not meet the above requirements. Once the stations have been identified, we have built the Voronoi polygons (Fig.3).

For each municipality the influencing stations were calculated on the basis of the Voronoi polygons and each station was associated with a weight equal to the ratio between the area of the polygon falling within the municipality and the total area of the municipality (Tab.5).

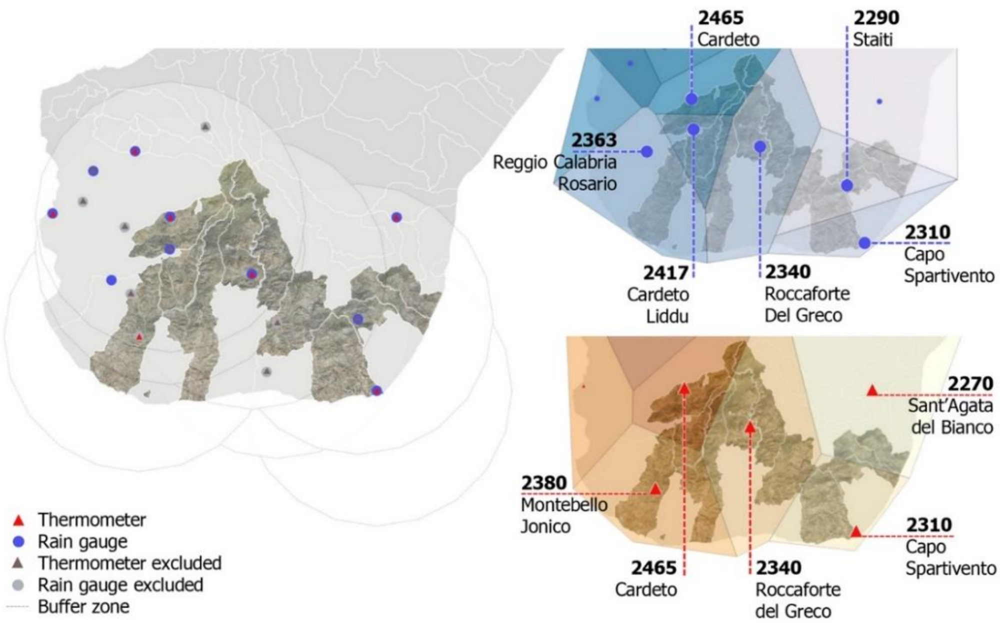

Fig.3 Climatic analysis

4.2. Grecanica Area: context analysis

In accordance with the proposed methodology, context analysis regards the assessment of sensitivity and adaptive capacity dimensions, respectively characterized by indices on agricultural sector and socio-economic features.

Particularly, the main source of data used by authors is Italian National Statistics Institute that provides information both for agriculture (ISTAT, 2010), population (ISTAT, 2011) and socio-economic conditions. Data on protected area are available on national Ministry of the Environment and the Protection of the Sea database (2020), while information about rural population are extracted from data of EUROSTAT grid (2011).

Especially for adaptive capacity analysis, in addition to already mentioned ISTAT data source, authors consulted Open Data of Italian Ministry of Economy and Finance (2019) for calculating municipal income per capita, while they carried out a municipality-by-municipality assessment for evaluating the presence of a municipal Emergency Plan.

Municipality		**Thermometer**			**Rain Gauge**		
ID	**Area (km²)**	**ID**	**Area (km²)**	**Weight**	**ID**	**Area (km²)**	**Weight**
01	29.83	2465	19.46	0.65	2465	3.45	0.12
		2380	9.32	0.31	2417	25.90	0.87
		2340	1.05	0.04	2363	0.48	0.02
02	46.51	2340	45.25	0.97	2340	24.46	0.53
		2310	1.26	0.03	2290	22.05	0.47
03	20.52	2270	14.32	0.70	2270	0.01	0.00
		2310	6.20	0.30	2290	20.51	1.00
04	37.24	2465	37.24	1	2465	20.75	0.56
					2417	15.91	0.43
					2363	0.57	0.02
05	18.92	2270	17.95	0.95	2270	3.93	0.21
		2310	0.97	0.05	2290	14.99	0.79
06	55.98	2380	53.76	0.96	2417	4.25	0.08
		2465	2.22	0.04	2363	51.73	0.92
07	52.36	2310	52.15	1.00	2290	24.75	0.47
		2340	0.21	0.00	2310	27.60	0.53
08	43.47	2340	37.30	0.86	2340	35.94	0.83
		2465	6.17	0.14	2465	7.53	0.17
09	44.88	2340	41.78	0.93	2340	36.53	0.81
		2465	2.55	0.06	2465	7.81	0.17
		2380	0.55	0.01	2363	0.55	0.01
10	63.89	2465	4.39	0.07	2465	2.86	0.04
		2340	25.23	0.39	2340	39.81	0.62
		2380	34.26	0.54	2417	16.97	0.27
					2363	4.26	0.07
11	16.16	2310	15.59	0.97	2290	1.62	1.00
		2270	0.56	0.03			

Tab.5 Grecanica Area: station weigth

In Italy, Civil Protection is the responsible Body for emergency management and every municipality is forced to have an Emergency Plan according to dispositions of Italian Legislative Decree 1/2018. Still today, however, not everywhere there is a plan or, where present, it is not properly update.

A research carried out by Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering (DINCI) of the University of Calabria, has highlighted the critical situation of emergency planning in Calabria Region at early 2017 (Francini et al., 2018).

		Index	01	02	03	04	05	06	07	08	09	10	11
EXPOSURE	Clim-1	FD0 (days)	29.0	11.5	0.9	43.0	1.2	3.2	0.3	16.2	13.4	8.5	0.3
		TR20 (days)	20.0	38.2	78.8	2.5	69.9	52.6	103.4	31.6	34.7	43.9	102.4
		TNx (°C)	23.1	26.9	27.9	20.9	27.7	27.0	28.5	26.1	26.6	26.7	28.5
		TNn (°C)	-5.5	-3.9	-0.1	-7.3	-0.6	-2.0	1.5	-4.5	-4.2	-3.1	1.4
		TN10p (%)	9.7	9.6	9.7	9.7	9.6	9.8	9.7	9.6	9.6	9.7	9.7
		TN90p (%)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.8	9.8	9.7	10.2
	Clim-2	SU25 (days)	49.9	69.0	113.7	33.1	113.1	81.2	115.0	62.8	65.9	73.6	115.1
		TXx (°C)	32.5	34.4	37.0	31.1	37.4	35.0	35.7	33.9	34.2	34.6	35.8
		TXn (°C)	-1.2	0.4	5.0	-3.1	4.2	2.3	7.2	-0.3	0.1	1.3	7.1
		TX10p (%)	9.6	9.7	9.6	9.5	9.7	9.7	9.5	9.7	9.7	9.7	9.5
		TX90p (%)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.7	9.8	9.7	10.2
		WSDI (days)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.7	9.8	9.7	10.2
	Clim-3	RX1day (mm)	67.2	103.8	92.2	91.9	103.2	121.1	75.8	114.6	114.7	100.7	92.1
		RX5day (mm)	99.7	186.9	167.1	143.2	180.8	178.0	132.5	201.3	201.1	171.2	167.1
		R10 (days)	21.2	28.7	28.6	29.9	28.8	38.7	22.7	30.5	30.7	27.3	28.6
		R20 (days)	8.6	13.1	13.9	13.8	14.3	18.8	10.6	13.4	13.5	11.7	13.9
		R95P (mm)	443.8	675.7	643.6	596.4	669.0	740.4	516.6	711.5	712.3	629.2	643.5
		SDII (mm/day)	9.0	12.6	13.5	10.7	13.6	12.9	11.5	11.9	11.9	11.1	13.5
		Clim-4 (%)	50.29	27.07	16.55	2.54	18.14	47.17	62.91	0.00	4.89	32.32	32.29

Tab.6 Grecanica Area: indices' values of climatic analysis

Municipality	Francini et al., 2018	National Civil Protection, 2020	Elaboration year (in-depth analysis)	Final data
01	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2017	Presence of an updated Emergency Plan (not digital)
02	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2012	Presence of a not-updated Emergency Plan
03	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
04	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
05	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
06	Absence of an Emergency Plan	Presence of an updated Emergency Plan	2017	Presence of an updated Emergency Plan (not digital)
07	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2014	Presence of a not-updated Emergency Plan
08	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2012	Presence of a not-updated Emergency Plan
09	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
10	Absence of an Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
11	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan

Tab.7 Grecanica Area: SocEco-4 index assessment

The results show that 35% of Calabrian municipalities didn't have an Emergency Plan and in almost 50% of cases, although the plan was present, it was elaborated at least 20 years before.

Today the situation seems to be better and, although digital plans available for online consultation on WebGIS platform are very few, national Civil Protection states that 96% of Calabrian municipalities has an emergency plan[12], even if, particularly from Grecanica Area, in-depth researches describe a framework a little bit difference.By processing the historical series (1999-2019) and considering the weights associated with each station, the indices shown in Tab.6 were evaluated for each municipality.

For the specific aim of this study a not-available plan can't be considered as an element of adaptive capacity: for sure, in this case, people cannot be informed properly before and during a crisis.

According to these assumptions, information collected for case study municipalities are reported in Tab. 7. Tab. 8 Shows results of data collection for context analysis, with specific focus on sensitivity and adaptive capacity assessments.

	Index	01	02	03	04	05	06	07	08	09	10	11
SENSITIVITY	Agr-1 (%)	43.39	38.81	45.54	12.41	35.77	35.34	36.11	21.04	32.42	41.80	18.62
	Agr-2 (N)	278	198	126	122	144	821	166	75	91	717	39
	Agr-3 (%)	47.50	17.90	11.60	32.70	0.70	14.60	15.00	56.20	41.80	29.40	18.40
	Agr-4 (%)	6.00	5.00	8.00	22.00	29.00	12.00	14.00	0.00	0.00	12.00	5.00
	Agr-5 (%)	51.00	59.00	1.00	13.00	0.00	0.00	1.00	100.00	95.00	30.00	24.00
	Pop-1 (%)	14.97	32.10	31.71	69.54	20.54	21.02	8.53	40.55	9.13	12.89	47.67
	Pop-2 (-)	4.94	8.25	5.22	4.79	5.38	0.56	4.44	9.89	5.11	3.59	10.05
ADAPTIVE CAPACITY	SocEco-1 (€)	12768	13190	11642	11785	14659	13038	14069	14155	11769	13259	11886
	SocEco-2 (-)	102.31	99.48	101.04	102.84	99.34	103.83	102.80	101.30	108.28	104.61	102.47
	SocEco-3 (N)	3	2	4	6	3	13	4	3	3	10	0
	SocEco-4 (-)	0.66	0.33	0.00	0.00	0.00	0.66	0.33	0.33	0.00	0.00	0.00
	SocEco-5 (N)	0	2	0	2	1	0	1	0	0	0	1

Tab.8 Grecanica Area: indices' values of context analysis

4.3 Grecanica Area: vulnerability assessment

Results showed in Fig.4 are obtained for each dimension of exposure, sensitivity and adaptive capacity after normalization and aggregation operations.

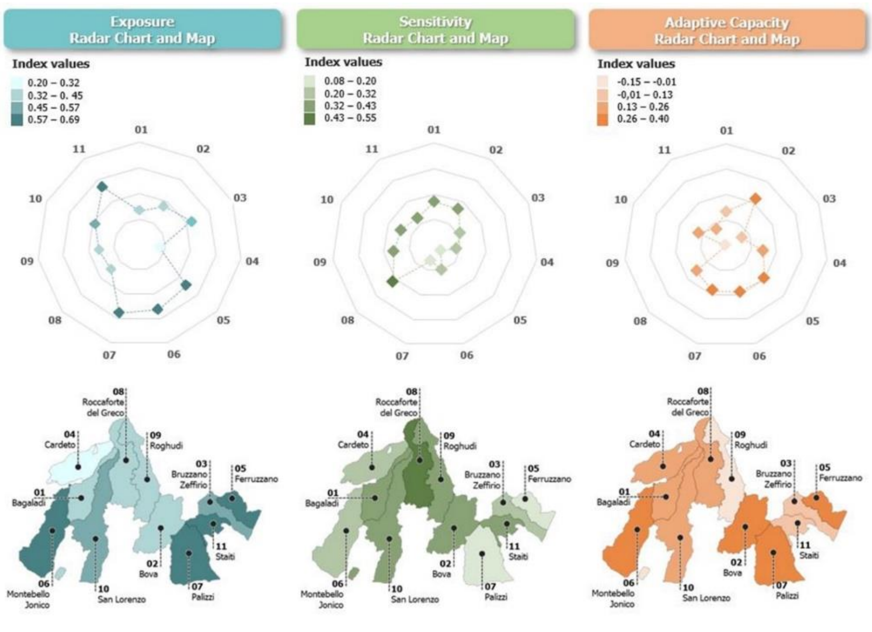

Fig.4 Index radar charts and maps of exposure, sensitivity and adaptive capacity assessments

[12] Information available at http://www.protezionecivile.gov.it/servizio-nazionale/attivita/prevenzione/piano-emergenza/mappa-piani-comunali/calabria

Vulnerability Index is calculated by combination of previous three dimension as established by Formula (3). Fig.5 presents the results described through a radar chart and a vulnerability map[13].

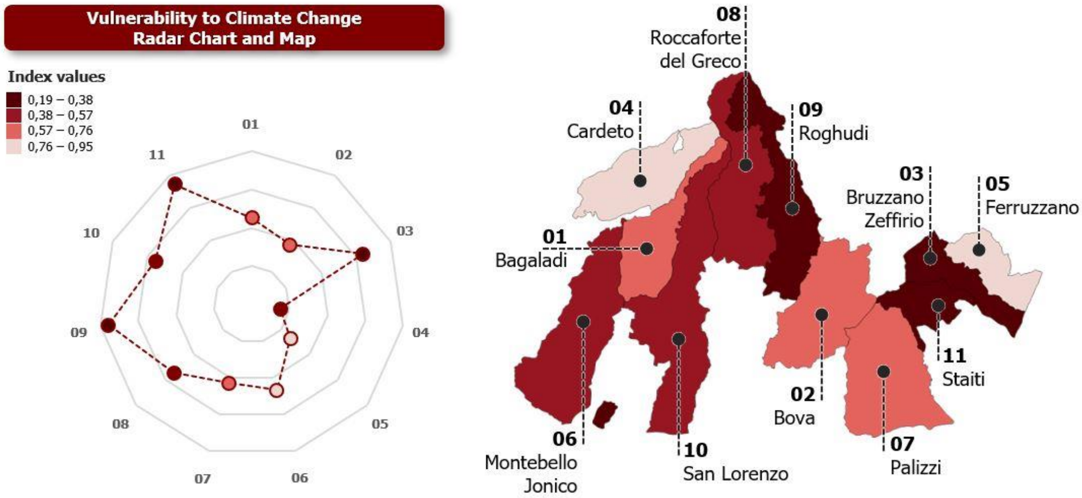

Fig.5 Grecanica Area: vulnerability index radar chart and vulnerability map

5. Discussion and conclusions

This paper proposes the application of a methodology to measure municipal vulnerability to climate change focusing on agricultural sector, through a Vulnerability Index (VI) that synthetize climatic and contextual factors (environmental and socio-economic) with respect to three components that are climatic exposure, sensitivity and adaptive capacity. The study area is composed by 11 municipalities with rural vocation located in province of Reggio Calabria (Southern Italy). Climatic analysis on the study areas have concerned extreme of cold, extreme of heat, extremes of precipitation and the desertification risk. The results show a significant level of exposure in all the municipalities observed with normalized values of the Exposure Index (EI) ranging between 0.20 and 0.69 (average value of 0.49 and standard deviation of 0.16). Municipalities that fall in areas most exposed to climate change ($EI > 0.5$) are nearly on 50% of all municipalities in the considered area. In particular, Palizzi has the highest exposure index (0.69), followed by Staiti (0.66) and Montebello Jonico (0.66). Cardeto has the lowest exposure index (0.20), followed by Bagaladi (0.33) and Roccaforte del Greco (0.37).

The context analysis has shown a significant dependence of the local economic system on agriculture (specifically, the indices Agr-1, Agr-2, and Agr-3 demonstrate this), which, combined with the significant level of exposure to climate change, demonstrates the importance of deepening studies on the level of local vulnerability. The context analysis led to the definition of the sensitivity index and the adaptive capacity index. Sensitivity Index (SI) ranging between 0.08 and 0.55 (average value of 0.31 and standard deviation of 0.14). Roccaforte del Greco has the highest sensitivity index (0.55), followed by Bagaladi (0.42) and Bova (0.42). In particular, in these three cases, Pop-2, Agr-5 and Agr-3 indices are particularly influential in the calculation of the index. Palizzi has the lowest sensitivity index (0.15), followed by Cardeto (0.21) and Montebello Jonico (0.25). Adaptive Capacity Index (ACI) ranging between -0.15 and 0.40 (average value of 0.19 and standard deviation of 0.16). Bova has the highest adaptive capacity index (0.40), followed by Ferruzzano (0.35) and Montebello Jonico (0.32). Roghudi has the lowest adaptive capacity index (-0.15), followed by Bruzzano Zeffirio (0.02) and Staiti (0.05). Overall, the Vulnerability Index was obtained as a function of the three aforementioned indices using formula (3). The Vulnerability Index (VI) ranging between 0.19 and 0.95 (average value of 0.61 and standard deviation of 0.23). The three most vulnerable municipalities are Roghudi ($VI = 0.95$), Staiti ($VI = 0.93$), and Bruzzano Zeffirio ($VI = 0.93$) and coincide with those with a lower level of adaptive capacity. The

[13] Vulnerability Index thresholds are obtained through the application of QGIS algorithm "equal interval".

results highlight the importance of taking measures to improve the adaptive capacity through the municipal planning.Starting from obtained results, authors compared them with indications of already cited SNAI Pilot Area and European LEADER Program elaborated for the same study area. Pilot Area Strategy[14] recognizes agricultural sector as a big development opportunity for local economy, providing specific actions detailed on E Intervention Sheet. However, no action aims at mitigating neither climate change effects nor other type of risks: moreover, no reference is done to current risk conditions neither in Annex A of territorial analysis to reflect the fact that seems to be no risk perception. Similarly, European LEADER Program, while identifying rural vocation of Grecanica Area and underling the state of abandonment of the lands and the lack of maintenance of agricultural activity, doesn't provide effective indications for possible mitigation measures and doesn't treat climate change at any point. Adaptive capacity goals are never mentioned in neither strategy.
Definitely, considering that Civil Protection Municipal Plan is currently the only tool treating the risk theme and that, however, it presents significant critical issues as specified in section 4.2., authors believe that two paths are possible: a review of Emergency Plan for inserting new vulnerability considerations as well as climate change ones in order to follow a new global preventive planning perspective; the introduction of a local Climate Change Adaptation Plan able to consider better specific characteristics of the area in a mitigation site-specific view. In particular, with reference to the first option, the integration with the new global preventive planning perspective could concern coordination with European policies such as SECAP for a vulnerability assessment that allows to define more detailed risk scenarios and consequent adaptation and mitigation actions in different policy sectors (Bertoldi, 2018) and for the different types of risk. In this sense, the role of the Civil Protection could concern the planning phase for the identification, evaluation and decisions on the discipline of land use, but also the phase of implementation of actions to combat climate change and the subsequent monitoring phase, as partly predicted by Neves, et al. (2016).
Enriching a sector plan of different contents and new objectives or introducing a new tool, however, wouldn't be enough: in order to make strategies more effective – especially at area level – ordinary planning process should be responsible of a better coordination among DDR and CCA approaches in "time of peace" and not only in emergency conditions.

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