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## Integrating climate change adaptation into municipal masterplans through Strategic Environmental Assessment (SEA)

A case study concerning Sardinia.

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### Abstract

Adaptation to climate change and the need to deal with its impacts pose in evidence how important it is to identify and implement new planning practices that integrate these profiles into land-use policy-making. Within this conceptual framework, the identification of a system of plan objectives and actions that characterize the integration of climate change adaptation into planning policies, with particular reference to the local scale, is of particular importance. In this study, a methodology for implementing this integration is proposed through the establishment of a logical framework for the construction of municipal masterplans through strategic environmental assessment, as a pathway in which plans are formed and developed, as part of the assessment process, through the identification of a strategic system of objectives and an operational system of planning actions based on the integration of climate change adaptation into the plan formation process.

### Keywords

Climate change adaptation; Strategic environmental assessment; Spatial policies; Strategic planning.

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## 1. Introduction

The integration of climate change adaptation (CCA) into strategic environmental assessment (SEA) processes is a widely discussed and analyzed issue in the technical and scientific literature.

During the preparation of Directive No. 42/2001/EC, an analytical research report on the implementation of SEA in the decision-making processes of plans and programs, prepared by the Imperial College for the European Commission (Sheate et al., 2001), emphasizes how the effectiveness of land-use policies at different scales, national, regional and local, is fundamentally linked to the integration of CCA issues, highlighting several profiles of these issues. Of particular relevance, among the many cases analyzed, are the SEA of the land-use plan of the city of Weiz (Austria), in which it is emphasized that "The targets, goals and objectives used in the SEA process are clearly defined, for example, carbon dioxide threshold according to the goals of the 'Climate Alliance'" (Sheate et al., 2001, p. 9), the SEA of the National Environmental Policy Plan 3 of the Netherlands, which places CCA among the reference themes for identifying the structure and framework of administrative and technical competencies of the decision-making process (ibid., p. 85), and the Regional Economic Strategy of the Yorkshire Regional Development Agency, which explicitly includes climate change among the components of the strategic framework (ibid., p. 153).

A very significant document is the Advisory Note on Environmental Assessment and CCA (ENVIRONET, 2010), which identifies four fundamental moments in the implementation of spatial planning processes that involve the integration of SEA and CCA: (i.) the precise and circumstantial identification of the universe of stakeholders and environmental components that reasonably will be affected, during the plan process, by the impacts of CCAs; (ii.) the implementation of the SEA; (iii) the process of informing and educating local communities, affected by the plan and climate change, in the proactive participation in the definition and implementation of planning policies; and, (iv) the continuous updating of the plan's strategic framework through the ongoing SEA and monitoring. A significant moment in the discussion proposed in the Advisory Note concerns the problematic nature of the conceptual and technical relationships between SEA and CCA. Indeed, it should be acknowledged and kept well in mind how SEA does not so much provide a conceptual and technical framework for the development of scientific research related to the impacts of climate change, but, rather, poses, in problematic terms, the need to fill knowledge gaps (ENVIRONET, 2010), which need to be kept in mind, if not resolved, as SEA is tasked with constructing frameworks and assessing impacts in reasonably plausible terms, which would not be possible if the gaps gave the assessment process a character of dramatic indeterminacy. SEA is effective in monitoring the implementation of plan processes, and, during this, the type and magnitude of climate change and, therefore, related adaptation measures, in relation to, for example, atmospheric precipitation, the genesis and likelihood of extreme weather events, the effects on water quality, and the generation of re-risk conditions, related to the hazard, vulnerability, and exposure associated with the impacts of climate change on natural resources and local societies.

An analytical discussion of this theoretical and technical conceptual vision is proposed by Wende et al. (2012), who examine, in comparative terms, SEA processes which integrate CCA approaches with reference to regional land-use plans from Saxony and East England.

A more comprehensive and general view of the relationship between SEA and CCA is, on the other hand, proposed and discussed by González Del Campo et al. (2020) with reference to SEA processes that integrate, in the strategic device of the assessment, specific objectives that refer to Strategic Development Goal No. 13 of Agenda 2030 (Partidário & Verheem, 2019), "Take urgent action to combat climate change and its impacts." The issue of integrating CCA into SEA processes is addressed, specifically, in the European Commission's document "Guidance on Integrating Climate Change and Biodiversity into Strategic Environmental Assessment" (McGuinn et al., 2013), which takes up and develops the contents of ENVIRONET's Advisory Note (2010).

The issue is discussed, in systematic terms, in the fifth section of the paper, in which some basic conditions for the construction of SEA environmental reports (ERs) whose strategic device, i.e., whose hierarchical system of objectives, includes CCA-relatable goals, integrated into the plan strategy, are discussed.

Related to what is presented and discussed in this study, of particular relevance is what is indicated regarding the need to address, in a detailed and specific manner, in ERs, the issue of consistency between the strategic device of the plan and the systems of objectives regarding mitigation and CCA identified in national and local strategies and plans focused on these issues (McGuinn et al., 2013, p. 70). In general, integrating the sustainability paradigm into public policy-making and implementation processes involves a careful assessment of economic and social equity issues in intra- and inter-generational terms (Francini et al., 2021). With regard, in particular, to spatial planning, this integration is not made operational through measures identifiable in deterministic terms, but, rather, through practices that involve an open and continuous dialectic with local societies, based on mediation in relation to the instances and expectations they express, as well as on the contributions of spatial sciences, to be used not only as foundational references of spatial analysis, but, also, as sources of collective learning (Gambino, 2005).

It is within this conceptual framework that the objective of this study is recognized and placed, which consists in the definition of a methodological approach for the integration of CCA in the ERs of the SEAs of the territorial plans of local governments that, in the Italian regulatory context, are identified as municipal masterplans (MMPs) (Isola et al., 2023a). It consists, therefore, in the implementation of a downscaling operation to the local level of strategies and plans concerning CCA, in force in the European and national contexts, that is, with reference to MMPs (Frigione & Pezzagno, 2023).

The starting point for the development of the downscaling process to municipal urban planning is the National Plan for Adaptation to Climate Change of Italy (NPCCA), whose strategic device declines the European Union Strategy for Adaptation to Climate Change (EUSCCA)<sup>1</sup> and the National Strategy for Adaptation to Climate Change of Italy (NSCCA)<sup>2</sup>.

The EUSCCA has had two versions, the first dating back to 2013, the other to 2021 (see footnote 1). The second is a critical restatement of the 2013 EUSCCA following an in-depth evaluative review of its implementation through the national CCA-related strategies and plans adopted and implemented by many EU countries<sup>3</sup>. The EUSCCA promotes, in this regard, the implementation of the conceptual and technical-operational framework of the EU Covenant of Mayors for Climate & Energy initiative<sup>4</sup>, for whose local plans and actions the JRC has defined a specific approach in a three-part guideline manual, of which the first proposes a detailed itinerary for the definition of a municipal action plan aimed at CCA and mitigation, and energy savings, the second refers to emission census, and risk and vulnerability assessment, and the third to the identification of best practices and key actions concerning CCA and mitigation, as well as financial issues (JRC, 2018a; 2018b; 2018c). The NSCCA was defined, in 2015, on the basis of the 2013 EUSCCA, and, as far as it concerns the integration of CCA into local plans, it offers some very important pointers, in implementation of the technical device of the EUSCCA.

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<sup>1</sup> The two reference documents of the European Commission concerning the EUSCCA are as follows: i) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "An EU Strategy on adaptation to climate change," COM(2013) 216 final; ii) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Forging a climate-resilient Europe - the new EU Strategy on Adaptation to Climate Change," COM(2021) 82 final.

<sup>2</sup> The reference document for the NSCCA is Decree No. 86 of the Director of the Directorate General for Climate and Energy of the Ministry of the Environment and Land and Sea of June 16, 2015, adopting and approving the NSCCA (Art. 1). The NSCAA is contained in the Annex to the Decree and is an integral part of it.

<sup>3</sup> The evaluation document is the Commission Staff Working Document "Evaluation of the EU Strategy on adaptation to climate change," SWD(2018) 461 final.

<sup>4</sup> An extensive and systematic information dossier on the initiative can be retrieved from the European Union website <https://eu-mayors.ec.europa.eu/en/home>. Accessed February 18, 2024.

In particular, the approach of the NSCCA individuates the reference areas for defining the situation of climate dynamics and climate change and, in relation to these, identifies impacts and vulnerabilities, with respect to which the objectives and actions of the NPCCA will be defined. These will form the foundational strategic device for the downscaling operation that is the objective of this study.

In the second section, the methodology used to carry out the downscaling is described, and the reasons for the choice of the four local contexts in relation to which the methodology is implemented are given, namely the cities of Capoterra, Selargius, Nuoro and Sassari. The ERs of the MMPs of the four cities are based on the declination, in the local spatial contexts, of the principle of sustainable development, in accordance with the provisions of Legislative Decree 152/2006 (Art. 3-quater, and Art. 4, paragraph 4, letter a), in line with the conceptual approach of the Brundtland Report (WCED, 1987). That scientific and technical framework highlights important issues, both theoretical and applicative, with reference to local government spatial planning practices. In the following section, the results of the downscaling operation are presented, in relation to the reference areas most relevant to this operation. Next, the characteristics that connote them, in terms of the strategic framework and planning actions, are described. An articulated discussion and policy implications are reported in the first and second section of the Supplemental material. The discussion is aimed at highlighting whether, and to what extent, the outcomes associated with the four Sardinian cities are generalizable, with reference to what is found in other similar cases relating to spatial contexts other than the territory of Sardinia. The concluding section highlights the prospects for the development of the research, also in relation to the problematic issues reported in the discussion of the results.

## 2. Methods and materials

This section is organized as follows. The first part is devoted to the analytical description of the methodology used for the integration of CCA into the ERs of the SEAs of MMPs. The second part presents the reasons for the choice of MMPs, related to four Sardinian cities, taken as a reference for the application of the methodological approach adopted.

### 2.1. Methodology

The NSCCA identifies reference areas for defining the situation of climate dynamics and climate change. In relation to these areas, it identifies impacts and vulnerabilities to which the objectives and actions of the NPCCA have been defined. The NPCCA has recently been adopted and is currently undergoing the SEA process, according to the Ministry of Environment and Energy Security's announcement<sup>5</sup>.

The current version may, therefore, not be the one that will be approved as a result of any changes made following the completion of the SEA. For the purposes of this study, this version is assumed to be reasonably close to the final draft of the Plan, as its current structure has remained unchanged since the time of its first online publication in 2018. Since then, it also has been subject to the scrutiny of all interested public administrations, at the state, regional and local levels, registering a generalized consensus. The NPCCA is, therefore, the operational extension of the NSCCA, of which it maintains the taxonomy of 18 reference sectors identified. The identification of plan objectives and actions is based on a context analysis, which deepens that of the NSCCA, based, as noted in the fourth chapter of the NSCCA, on the identification of impacts and vulnerabilities associated with each of the 18 reference sectors.

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<sup>5</sup> See, in this regard, the press release retrieved from: <https://www.mase.gov.it/comunicati/pubblicato-sul-sito-del-mase-il-piano-di-adattamento-ai-cambiamenti-climatici>. Accessed February 18, 2024. This bears "Climate Change Adaptation Plan published on MASE website," which gives notice that the NPCCA has been published for SEA purposes. The NPCCA can be retrieved from: <https://www.mase.gov.it/pagina/piano-nazionale-di-adattamento-ai-cambiamenti-climatici>. Accessed February 18, 2024.

The methodology for the integration of the CCA into the ERs and, therefore, for the construction of the MMPs, consists of three phases, basically geared toward grafting the NPCCA's device of objectives into the systems of objectives of the MMPs. It should be noted that the application of the methodology proposed in this section, which refers to the adopted NPCCA, could be replicated with reference to any future drafts of the NPCCA, whose strategic framework, represented by the system of objectives of the updated version, would need to be incorporated. Among the objectives of the NPCCA, systematized in Annex IV of the NPCCA, called "Database of Actions"<sup>6</sup>, the first phase aims to identify those that can be associated with the processes of defining MMPs, having significant implications on land governance. Based on the objectives of CCA, and also taking into consideration the 18 NPCCA Reference Sectors<sup>7</sup> to which they refer, a selection of significant objectives relevant to land-use and urban planning is made, followed by an identification of the actions/measures referring to them. The second stage is the construction of the system of specific objectives of the MMPs to which the ERs refer, that is, the construction of the logical frameworks (LFs) of the ERs of the MMPs, systems that are deduced directly from the ERs of the MMPs.

Finally, in the third phase, the objectives identified in the first phase are used in the drafting of the ERs for the construction of the MMPs as operational references to redefine the systems of the specific objectives and actions of the MMPs so that these systems integrate the CCA into the overall strategy of the MMPs.

The following sections describe the three steps in detail. Figure 1 provides an overview of the methodological steps presented in Sections 2.1, 2.1.1, 2.1.2 and 2.1.3, and the relations between actions from the four Sardinian MMPs and good practices from other case studies, as discussed in Sections 4.1, 4.2 and 4.3.

#### *2.1.1. Step 1: Targets of the NPCCA that can be associated with MMPs*

The first phase is aimed at identifying and selecting NPCCA objectives and actions that are relevant to land-use and urban planning. All 18 areas of the NPCCA were considered. Of the 137 Objectives defined in the NPCCA, 74 Objectives were found to be relevant to the analysis of possible effects on spatial governance. Subsequently, by the same process, out of the 360 Adaptation Actions referred to the 137 Goals, 253 Actions were identified as relevant to land-use and urban planning. Table 1 shows, as an example, the identification and selection of Objectives and Actions of the NPCCA with reference to the Sector "Hydrogeological instability." In the example, the actions are identified with reference to the NPCCA goal "Improving emergency management by administrations at all levels and increasing public participation." The table contains a summary description of each action, and an indication of the indicators that the NPCCA associates with the action.

#### *2.1.2. Step 2: Targets of the NPCCA that can be associated with MMPs*

The second phase consists in the construction of the system of the specific objectives of the MMPs to which the ERs refer, that is, the construction of the LFs of the ERs of the MMPs.

For the exemplification, which is proposed in the following third phase, reference is made to the Selargius MMP, which is a plan that has completed the process of adaptation to the Regional Landscape Plan (RLP)<sup>8</sup> and the Sectoral Plan for the hydrogeological framework (SPHF), and whose documentation is integrally available online in the institutional website of the Municipality of Selargius<sup>9</sup>.

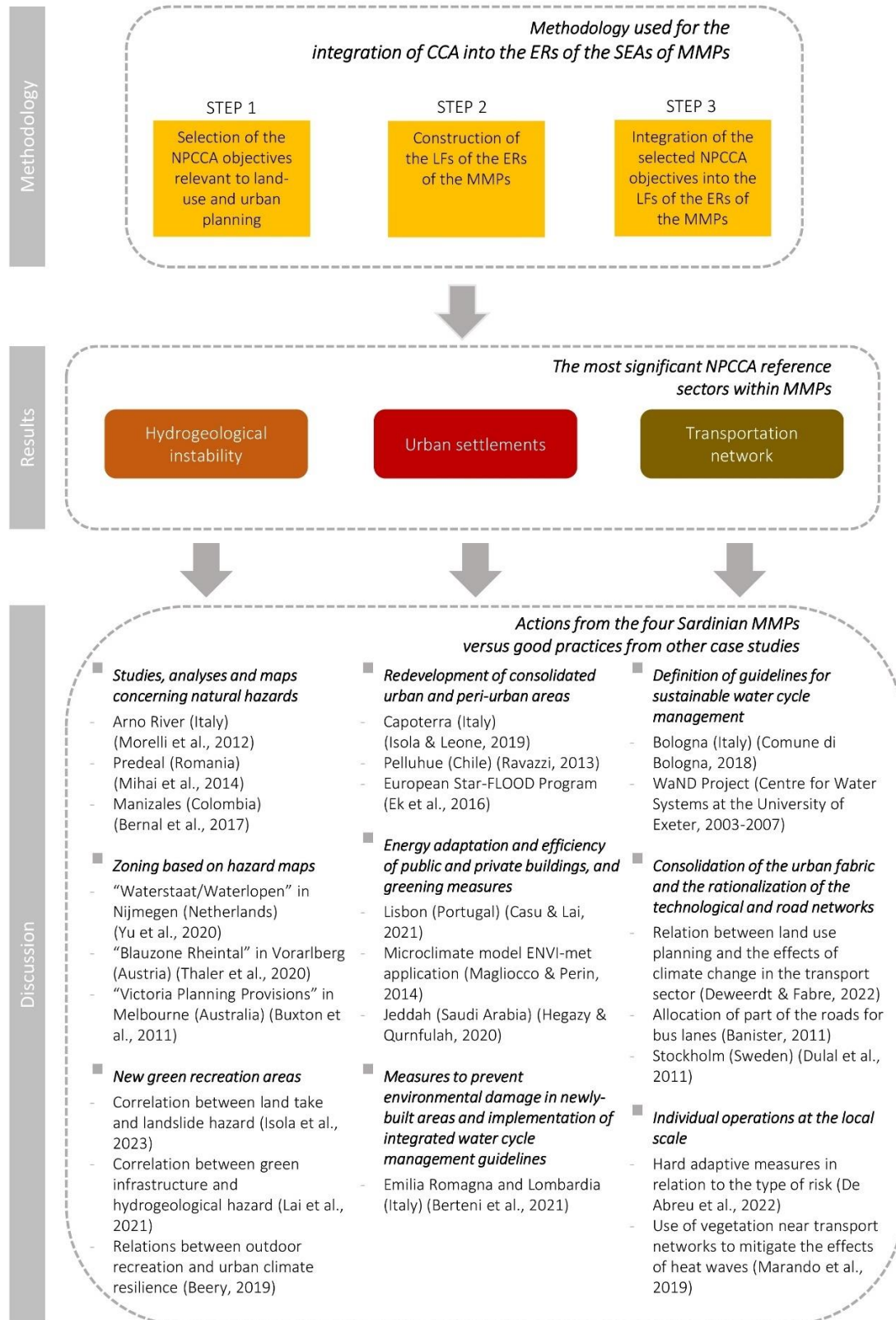
<sup>6</sup> Retrieved from: [https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/PNACC\\_AllegatoIV\\_database\\_azioni.ods](https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/PNACC_AllegatoIV_database_azioni.ods). Accessed February 18, 2024.

<sup>7</sup> Aquaculture; Agriculture and food production; Desertification, land degradation and drought; Geological, hydrological and hydraulic instability; Ecosystems and biodiversity in inland and transitional waters; Marine environments: Biodiversity, Functioning and Ecosystem Services; Energy; Terrestrial Ecosystems; Forests; Hazardous Industries and Infrastructure; Urban Settlements; Cultural Heritage; Marine Fisheries; Water Resources; Health; Transport; Tourism; Coastal Zones.

<sup>8</sup> Documents retrieved from: <http://www.sardegna.territorio.it/paesaggio/pianopaesaggistico2006.html>. Accessed February 18, 2024.

<sup>9</sup> Retrieved from: [https://www.comune.selargius.ca.it/amministrazione\\_trasparente/index.php?i1=19&i2=60&i3=98](https://www.comune.selargius.ca.it/amministrazione_trasparente/index.php?i1=19&i2=60&i3=98). Accessed February 18, 2024.

The environmental sustainability objectives, defined in the Selargius MMP as “General Objectives,” and the Specific Objectives were extrapolated from the ER of the Selargius MMP, where they are clearly spelled out, while, as far as the plan actions are concerned, the set of actions in the ER was integrated with the actions reported in the Selargius MMP’s elaboration No. 37 “Quadro Logico del MMP”.



**Fig. 1 Overview of the methodological approach and relations between actions from the four Sardinian MMPs and good practices from other case studies discussed in Sections 4.1, 4.2 and 4.3**

<b>SECTOR</b>	Hydrogeological instability		
<b>OBJECTIVES</b>	Improving emergency management by administrations at all levels and increasing public participation		
<b>ACTIONS / MEASURES</b>	Improved forecasting systems-innovative methods of collecting information	Improved technical support, emergency management, and preparedness and training-guidelines for technical design	Improved technical support, emergency management, and preparedness and training-techniques for emergency management
<b>DESCRIPTION</b>	Analysis of innovative information collection and monitoring methods	Development of Guidelines for engineering design in non-stationary environment	Developing emergency management techniques based on interdisciplinary approach
<b>INDICATORS</b>	<ul style="list-style-type: none"> <li>- Number of early warning systems updated to take into account climate change and adaptation.</li> <li>- Number of registered users of early warning systems and information services.</li> <li>- Increased number of administrations using scientific evidence to support decision and policy making.</li> <li>- Improved catalog of knowledge tools (decision support tools (DST), other tools, technologies, methodologies, etc.) to support adaptation</li> </ul>	<ul style="list-style-type: none"> <li>- Number of projects funded</li> <li>- Number of regions updating their reference standards</li> </ul>	<ul style="list-style-type: none"> <li>- Number of technical reports, publications, and scientific communications relevant to civil protection organization at the local level</li> <li>- Increase in the number of actors/organizations involved in international support networks relevant to adaptation</li> <li>- Increased regional and national coverage of the monitoring carried out</li> </ul>

**Tab. 1 Identification and selection of NPCCA Objectives and Actions that are relevant to spatial and urban planning**

*2.1.3. Step 3: Integration of NPCCA objectives into the LFs of the ERs of the MMPs*

The integration of the NPCCA strategic framework into the LFs of the MMPs is exemplified in Tab. 2, which shows the structure of the assessment matrix. The matrix has been populated through the following sub-steps:

- comparison of all specific objectives of the MMP (column [b]) with all the objectives of the NPCCA relevant to land-use and urban planning (column [a]), selected in the first stage, also in light of the plan actions referred to them. At the end of the series of comparisons, column [c] is populated, which, for each specific objective of the MMP, lists all NPCCA objectives with respect to which it is relevant.
- For each specific objective of the MMP, assessment of the level of integration of all NPCCA objectives for which relevance was found. Column [d] is thus populated, in which the specific objective is either kept unchanged in case it integrates all relevant NPCCA objectives, or is reformulated, in case the integration with one or more NPCCA objectives is only partial, so as to improve the level of integration.
- Comparison between the NPCCA objectives relevant to the specific objectives of the MMP and all MMP actions (column [e]) that, in the strategic framework referred to in the second step, are linked to those specific objectives. In this sub-step, column [f] is populated, making explicit the ways in which each action contributes to the achievement of the NPCCA objective to which it is linked through the specific objective, and, where appropriate, indicating any corrections or arrangements needed to raise the level of integration. Non-relevant actions are excluded from the assessment.

The final result of the assessment conducted through the LF approach is presented through a matrix in which there are NPCCA goals relevant to specific objectives of the MMP stated in the ER, and plan actions related to them. Tab. 3 shows an example related to the Selargius MMP.

[a]	[b]	[c]	[d]	[e]	[f]
Objective of the NPCCA	Specific objectives of the MMP	Assessment of relevance between the NPCCA Objective and MMP objectives	Reframing the specific objectives of the MMP in terms of CCA	MMP actions related to the specific objectives and consistent with the NPCCA Objective	Evaluation of MMP actions in relation to the NPCCA objective
...	...	...	...	...	...

**Tab. 2 Evaluation matrix for the integration of NPCCA Objectives into the LF of MMPs' ERs**

Column [d] in table 2 shows the new formulation of the specific objectives of the MMP's ER LF, which incorporates the NPCCA strategic framework, thus its regional declination in the CCA, as the specific objectives of the MMP have been reformulated to be consistent with those of the NPCCA. The MMP actions themselves are evaluated in relation to their consistency with the NPCCA Goals (last column of Tab. 2).

## 2.2. Choice of spatial context

Sardinia, an autonomous region of Italy located in the western Mediterranean area (as shown in fig. 2, panel "A"), covers an area of approximately 24,000 square kilometers and is home to a population of 1,639,591 residents.

The choice of Sardinia as a case study for this study is due to its insular status, which simplifies the investigation of environmental issues on a regional scale.

Additionally, the island's climate exhibits a remarkable consistency, featuring hot and dry Mediterranean summers and mild winters with moderate rainfall (Canu et al., 2015). The landscape is predominantly characterized by hills, with only a few plains, notably the Campidano plain (the prominent greenish area in fig. 2, panel "B"), which is of significance for agricultural purposes. Several small coastal valleys are also present, but their agricultural potential is compromised by coastal urbanization pressures. Sardinia boasts several mountain ranges, none of which exceed 2,000 meters in height, contributing to the island's rugged terrain (Pungetti et al., 2008).

Regarding land cover, Sardinia is distinguished by its herbaceous vegetation associations, many of which are endemic, as well as by its scrubland, comprising Mediterranean maquis and garrigue (Cardil et al., 2014). Agriculture and pastures, including wooded grasslands resembling Spanish dehesas (Seddaiu et al., 2013), play a significant role.

These multifunctional agro-sylvo-pastoral systems consist of pastures featuring oak and cork oak trees. Urbanized areas constitute less than 3.8% of the region's land, a notably low figure compared to the Italian average, which was recently assessed at 7.6% (Munafò, 2019).

The ongoing practice of spatial planning in the Region of Sardinia is based on the adaptation of MMPs to the RLP and the SPHF, which involve the implementation of SEA processes within which, in endoprocessual terms, the MMP is produced and, essentially, identified, with the development of the assessment, according to the LF approach described in Section 2.1, with particular reference to the integration of the CCA in the construction of the system of objectives and plan actions (Tab. 1 through 3).

The selection of MMPs for testing the methodology for implementing CCA in SEA processes was based on the following criteria:

- cities with approved MMPs in accordance with RLP and SPHF;
- cities with significant population for the Sardinian context;
- availability of plan and SEA documents on cities' institutional websites.



Objective of the NPCCA	Specific objectives of the MMP	Assessment of relevance between the NPCCA Objective and MMP objectives	Reframing the specific objectives of the MMP in terms of CCA	MMP actions related to the specific objectives and consistent with the NPCCA Objective	Evaluation of MMP actions in relation to the NPCCA objective
Encourage and support ecosystem service-based solutions aimed at preventing and mitigating the effects of extreme events attributable to climate change	Protect the qualitative and quantitative status of surface and subsurface water resources	Objectives of the NPCCA relevant to the objective of the MMP (previous column):	Protect the qualitative and quantitative status of surface and groundwater resources while ensuring the permanence and functionality of associated ecosystems	Provision of precautionary measures in new residential expansion areas and guidelines for sustainable management of the water cycle: application of the principle of hydraulic invariance in new developments, with the construction of the lamination and rainwater collection tanks in individual lots	Collecting tanks and lamination basins distributed throughout the lots contribute to retention and thus mitigation of the effects of flood events
		i) improve land management and maintenance;			
		ii) ensure the functionality of river ecosystems even in lean periods, environmental sustainability of water resource uses, and socioeconomic sustainability of related activities;			
		iii) encourage and support ecosystem service-based solutions aimed at preventing and mitigating the effects of extreme events attributable to climate change;			
		iv) improve the efficiency of the water supply system in periurban areas, suburbs, historic centers, and public spaces;			
		v) increase soil permeability and hydraulic system efficiency in periurban areas, suburbs, historic centers and public spaces;			
		vi) promote planning and design for hazard prevention and facilitating monitoring;			
		vii) increase or change the velocity and volume of water runoff;			
		viii) improve the efficiency of water infrastructure;			
		ix) operationally define risk assessment procedures and enhance the resilience of integrated water services;			
		x) implement testing of materials, structures, facilities, and technologies that are more resilient to increasing temperatures and rainfall variability;			
(xi) secure land in relation to hydrogeological risk.					

**Tab. 3 Construction of the LF that integrates NPCCA objectives MMP specific objectives and plan actions – Example referred to the Selargius MMP**

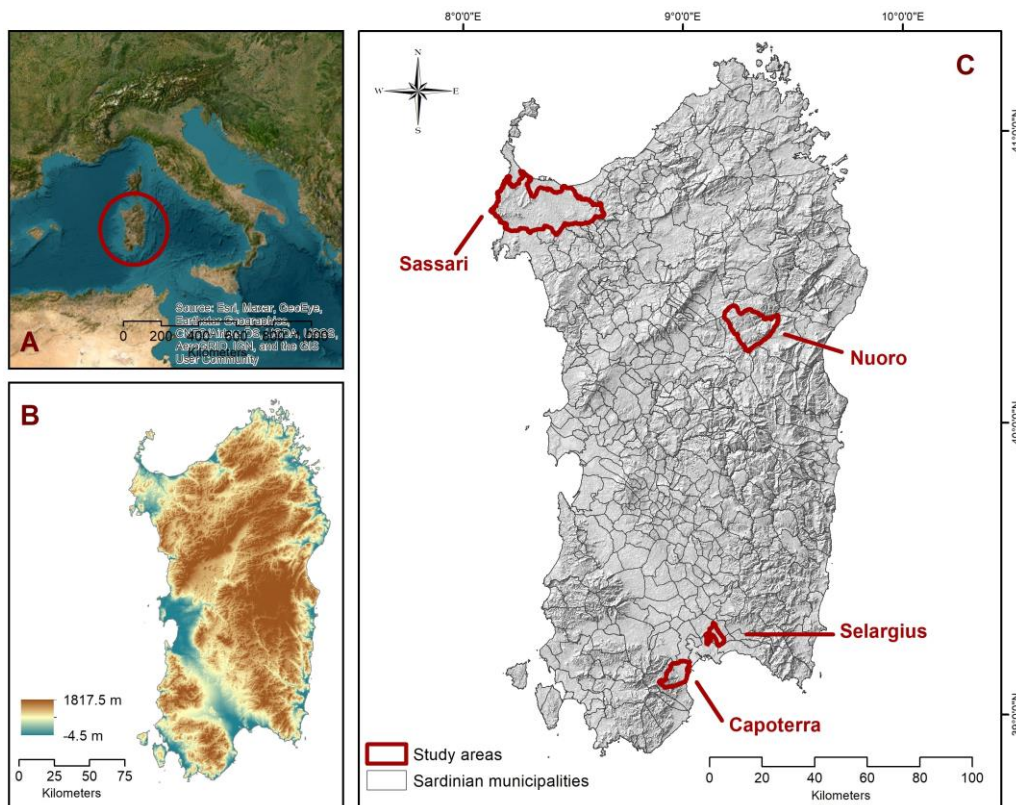
For the first criterion, the monitoring registry of municipal planning instruments freely available on the regional geoportal was used as a data source, which led to the identification of about thirty municipalities with approved MMP compliant with the SPHF and the RLP<sup>10</sup>.

The subsequent population relevance criterion, using a threshold of 20,000 inhabitants, narrowed the number of municipalities from about thirty to fewer than ten. Finally, based on the criterion of full availability of plan and SEA documents, the four selected case studies, namely the municipalities of Capoterra, Nuoro, Sassari, and Selargius, were identified from among the ten plans.

Capoterra, with its approximately 24,000 residents and 68 km<sup>2</sup> of land area, and Selargius, with approximately 29,000 residents and 27 km<sup>2</sup> of land area, are two important urban centers in the Metropolitan City of Cagliari, whose municipal territories are adjacent to that of the Regional Capital City to the west and north, respectively. Nuoro, a provincial capital of Sardinia and the administrative landmark of the region's central mountainous areas, has a resident population of about 34,000 and an area of 192 km<sup>2</sup>.

Sassari, the urban center capital of the Metropolitan City of Sassari, recently established under the provisions of the Regional Law No. 2021/7, is located in the northwest of Sardinia, in a predominantly flat territory with periurban belts characterized by an extensive presence of olive groves. Sassari has an area of 547 km<sup>2</sup> and a resident population of about 121,000.

For these four municipalities, whose locations are shown in figure 2, panel "C", the ERs of the SEAs and the MMPs documents, such as general report and technical implementation rules, are analyzed in order to define the respective LFs that contribute to the overall scheme in Tab. 3.



**Fig.2 Sardinia within the Mediterranean Basin (A); Topographic map of Sardinia (B). The four municipalities selected as case studies (C)**

<sup>10</sup> The thematic navigator can be retrieved from: [https://www.sardegnaegeoportale.it/webgis2/sardegnaegeoportale/?map=monitoraggio\\_strumenti\\_urbanistici](https://www.sardegnaegeoportale.it/webgis2/sardegnaegeoportale/?map=monitoraggio_strumenti_urbanistici). Accessed February 18, 2024. Data extrapolation from the attribute table of the shapefile "Monitoraggio strumenti urbanistici comunali, PUL, PP centri matrice e ripermetrazioni centri matrice" was carried out in December 2021. The shapefile was retrieved from: [https://webgis2.regione.sardegna.it/geonetwork/srv/ita/catalog.search#/metadata/R\\_SARDEG:4c48fe46-1014-4846-ae83-39c3be986b99](https://webgis2.regione.sardegna.it/geonetwork/srv/ita/catalog.search#/metadata/R_SARDEG:4c48fe46-1014-4846-ae83-39c3be986b99). Accessed February 18, 2024.

### 3. Results

The NPCCA reference sectors that stand out as the most significant within the MMPs of the four cities in Sardinia selected for the implementation of the methodology described in the second section of this study are hydrogeological instability, which is characterized by 31 specific objectives and 50 plan actions, urban settlements, with 29 specific objectives and 47 plan actions, and transportation, with 40 specific objectives and 62 plan actions. This section is divided into three parts and presents the results for each of these areas in relation to the definition of objectives and operational plan choices that integrate CCA into the LFs, i.e., strategic and implementation arrangements, of the MMPs.

#### 3.1. Hydrogeological instability

The full set of actions and measures contained in the LFs of the ERs of the four analyzed MMPs that integrate climate considerations and contribute to addressing hydrogeological instability is provided in table 4 (third column), together with the objectives from which they descend within each LF (second column), and the NPCCA's goals that are pursued (directly or indirectly, to a larger or lesser extent) through the plans' objectives and action (first column). Three NPCCA's goals have been found to be pursued by the four the LFs of the ERs of the MMPs; two out of three aims at enhancing knowledge, either on areas that are prone to hydrogeological issues within the administrative boundaries, or on the conditions of buildings and infrastructure, while the third goal is action-oriented and paves the way for either revised planning choices or tangible actions.

The first objective, concerning improved knowledge on critical geological and hydraulic issues, is integrated within Sassari's and Selargius' LFs, which both contain an action providing for the identification of areas characterized by hydrogeological hazard and risk. Such action stems from a single objective in Sassari's LF and is connected to three objectives in Selargius LF.

The second objective, concerning improved knowledge on the conditions of buildings and infrastructure with a view to increasing their resilience, is integrated within three LFs of the ERs of the MMPs (Capoterra, Sassari, and Selargius). As for Selargius, a single action, providing for mitigating hydrogeological risks, hence focusing on the resilience part, stems from two LF objectives, while in the two other LFs a one-to-one relation between action and objective can be observed.

In Capoterra, the action focuses on the coastal areas, where a critical infrastructure, the road connecting the regional capital with Capoterra and the southwestern part of Sardinia, lies over a narrow strip of land, constrained between the coastline and a large wetland.

In Sassari, the action focuses on former mining sites, which also include abandoned buildings forming the old mining hamlets, as knowledge on their status is a precondition for their recovery and reuse for tourism purposes.

Finally, the last objective, concerning improved land management and maintenance, is integrated within all of the four analyzed LFs of the ERs of the MMPs, by means of one action (connected to a single objective) in both Capoterra and Sassari, of three actions (connected to four objectives) in Selargius, and of seven actions (connected to seven objectives) in Nuoro.

The broad goal of enhancing land management and maintenance is variously pursued in the four LFs, whose actions range from studies and analyses, to the identification of rules to be included within the municipal planning implementation code, to tangible interventions aimed at addressing specific problems within the town, as in the case of the conversion of the former railroad and of landscaping actions in Nuoro, or of the recovery and reuse of former mining hamlets in Sassari, or of measures to mitigate hydrogeological hazards in Selargius and to improve the coastal area in Capoterra.

### 3.2. Urban settlements

With reference to urban settlements, Tab. 5 in the Supplemental material shows that all four MMPs develop strategies aimed at defining objectives and actions aimed at mitigating climate change negative impacts, and at adapting urban environments.

The NPCCA's objective concerning the improvement of thermal comfort and quality of living involves establishing measures for heat control, storage, and dissipation. The objective is fully implemented into the LFs of the ERs of the four analyzed MMPs through: i. two specific objectives in the LF of the ER of the Capoterra MMP; ii. eight specific objectives in the LF of the ER of the Nuoro MMP; iii. eight specific objectives in the LF of the ER of the Selargius MMP; and, iv. two specific objectives in the LF of the ER of the Sassari MMP. In relation to these objectives, two types of plan actions have been identified to achieve the NPCCA's objective: the first aims at redeveloping and recovering the built characteristics of the urban consolidated fabric, while the second concerns the redevelopment of peripheral, periurban and rural spaces.

This redevelopment pursues the strategic distribution of greenery to mitigate impacts due to solar radiation and the heat island effect (Isola et al., 2023b).

As for Capoterra, four plan actions are of the first type, while three plan actions refer to the second type. Both clusters of actions are associated with the same LF objectives. In the case of Selargius, most of the plan actions are aimed at creating green areas and improving the conditions of existing ones.

The actions are associated with the objective "To pursue an environmental policy aimed at increasing the quantity and quality of green spaces present in the urban and suburban context and to encourage processes of reconfiguration and regeneration of the same through raising the building quality of public spaces and facilities." The actions of the LF of the ER of the Nuoro MMP are, in general, oriented toward the redevelopment of the landscape and built environment, with particular attention to the endowment of urban standards, the enhancement of the built urban fabric and the redevelopment of some of the most important sites of historical and cultural interest.

The LF of the ER of the Sassari MMP, on the other hand, defines a plan strategy that, with reference to the objective of the NPCCA, focuses on the partially unbuilt areas within the urban center, through the inclusion of a share of non-developable areas to make room for an urban network of green areas. These plan actions pursue the objective of reconnecting the most significant urban voids.

Regarding the NPCCA's objective concerning the improvement of the efficiency of the water supply system in periurban areas, suburbs, historic centers and public spaces, it is worth noting that the issue of water resource management is a nationwide problem. Regarding the LFs of the MMPs' ERs, the NPCCA goal is implemented into all of the four plans. In the case of Capoterra, six plan actions stem from a single LF objective alone related to the redevelopment and reorganization of consolidated urban hubs. As for Nuoro, ten plan actions referring to this NPCCA objective, and they derive from as many objectives of the LF of the MMP, largely aimed at enhancing the existing built and cultural heritage and ensuring the provision of new public services. The same aims are pursued in the LF of the Selargius MMP, in which thirteen plan actions implement the NPCCA objective and are associated with a set of specific objectives aimed at protecting the qualitative and quantitative state of water resources, preventing hydraulic and geological risk, and increasing the availability of quality green spaces in the urban, periurban and rural areas. The LF of the ER of the Sassari MMP targets two plan actions that relate to improving the efficiency of the water system; both refer to the need to define an urban ecological network and are linked to two different objectives of the LF.

The third and fourth objectives of the NPCCA aim to promote planning and design for risk prevention and to facilitate monitoring and increasing soil permeability and hydraulic system efficiency in periurban areas, suburbs, historic centers, and public open spaces. Both objectives aim to address these critical issues and are integrated into the LFs of the ERs of the analyzed MMPs.

NPCCA goals	LF objectives	LF actions
To improve land management and maintenance.	<u>NUORO – To regulate building expansion.</u> <u>NUORO – To restore areas currently hosting illegal buildings.</u>	Analysis of the residential and service systems.
To improve land management and maintenance.	<u>SELARGIUS – To ensure soil conservation and protection.</u>  <u>SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.</u>  <u>SELARGIUS – To prevent new hydrogeological hazards.</u>	Restrictive rules for Subareas C3.1 (residential) and G1.4 (services and facilities), classed as areas prone to high and very high geological hazard. Their implementation in terms of urban planning and construction is subject to the execution of hydraulic works of mitigation, regimentation and regularization of the current hydrogeological risk, so as to eliminate constraints arising from the current classification under the SPHF
To improve knowledge on critical geological and hydraulic issues in the area and their associated risks, and to produce updated databases based on land monitoring.	<u>SASSARI – To prevent hydrogeological risks through appropriate land use regulations.</u> <u>SELARGIUS – To ensure soil conservation and protection.</u> <u>SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.</u> <u>SELARGIUS – To prevent new hydrogeological hazards.</u>	Identification of areas characterized by hydrogeological hazard and risk.
To improve land management and maintenance.	<u>NUORO – To ensure the endowment of public services and facilities.</u> <u>NUORO – To enhance the area of the former powder mill in Prato Sardo.</u>	Allocation of new areas for sports and recreation.
To improve land management and maintenance.	<u>NUORO – To reclaim areas with illegal buildings.</u> <u>NUORO – To take action on the “Testimonzos” area in accordance with current regulations.</u>	Preparation of a landscape-oriented redevelopment plan.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience.	<u>SELARGIUS – To ensure soil conservation and protection.</u> <u>SELARGIUS – To prevent new hydrogeological hazards.</u>	Interventions aimed at mitigating hydrogeological risks.
To improve land management and maintenance.	<u>SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.</u> <u>SELARGIUS – To prevent new hydrogeological hazards.</u> <u>SELARGIUS – To ensure soil conservation and protection.</u>	
To improve land management and maintenance.	<u>SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.</u> <u>SELARGIUS – To prevent new hydrogeological hazards.</u> <u>SELARGIUS – To ensure soil conservation and protection.</u>	Precautionary measures in new residential expansion areas and guidelines for sustainable management of the water cycle: the principle of hydraulic invariance shall be applied in new development, and individual lots will be equipped with lamination and rainwater collection tanks.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience.	<u>SASSARI – To reactivate the Argentiera tourist system.</u>	Functional-architectural recovery and securing of former mining areas
To improve land management and maintenance.	<u>SASSARI – To reactivate the Argentiera tourist system.</u>	
To improve land management and maintenance.	<u>NUORO – To ensure the endowment of public services and facilities.</u> <u>NUORO – To enhance the area of the former powder mill in Prato Sardo.</u>	Conversion of the former railroad into a bicycle and pedestrian pathway.
To improve land management and maintenance.	<u>NUORO – To contain the built environment within an ideal perimeter.</u> <u>NUORO – To regulate building expansion.</u> <u>NUORO – To plan and develop a linear park that includes equipment and services of public interest.</u>	Redesign of the zoning scheme.
To improve land management and maintenance.	<u>NUORO – To ensure the endowment of public services and facilities.</u>  <u>NUORO – To regulate building expansion.</u>	Redevelopment of the railway station area by maintaining the existing destination while also providing for new volumes for residential, commercial, and office uses, as well as for a new “park and ride” area.
To improve knowledge of the conditions of the buildings and infrastructure to increase their resilience.	<u>CAPOTERRA – To protect and maintain environmental, historical and cultural components in order to recover historical memories and preserve landscape areas of particular importance, while also considering safety issues within the municipal areas, so as to promote its sustainable development by mitigating, or even reconsidering, incompatible urban planning expectations.</u>	Improvement of the coastal area, mitigation of current erosion phenomena, conservation of the ecological systems (beach and wetland), environmental recovery of the wetland system for both productive and naturalistic purposes, reorganization of the coastal renaturalized landscape, environmental land rehabilitation for tourism purposes.
To improve land management and maintenance.	<u>NUORO – To ensure the endowment of public services and facilities.</u> <u>NUORO – To enhance the area of the former powder mill in Prato Sardo.</u>	New green recreation areas and landscaping.

**Tab. 4 Goals related to hydrogeological instability contained in the NPCCA and integrated within the four analyzed logical frameworks (LF) of the MMP’s environmental reports, LF’s objectives and actions and measures that contribute to pursuing the NPCCA objectives**

The third objective is present in three of the LFs of the ERs of the analyzed MMPs, with the exception of Sassari, while the fourth is implemented into all four plans. As far as Capoterra is concerned, six plan actions contribute to the achievement of the NPCCA's third objective, all referring to the same specific objective of the LF of the ER of the MMP, namely the redevelopment and reorganization of the consolidated urban poles, i.e., the urban consolidated fabric, the Poggio dei Pini hamlet and the coastal strip. Also referring to Capoterra, six plan actions are associated with the fourth objective of the NPCCA. Among them, some implement the LF objective focused on the protection and preservation of environmental, historical and cultural components, and the protection of areas of special landscape significance; others pursue the LF objective of spatial and environmental safety.

### 3.3. Transportation network

The LF, reported in tab. 6 in the Supplemental material, provides: i. in the first column, the NPCCA's goals directly or indirectly pursued by objectives and actions of the LFs of the ERs of the analyzed MMPs; ii. in the second column, the objectives of the four LFs of the ERs of the MMPs with which the objectives of the NPCCA are associated; and, iii. in the third column, the actions that implement the LFs' objectives, integrate climate considerations, and contribute to addressing transportation network.

Four NPCCA's goals have been found to be pursued by the four LFs. Two objectives refer to prevention measures, such as promoting the securing of the territory against hydrogeological risk and the integrating climate change risks into planning and design processes. One objective refers to monitoring measures. Finally, the last objective refers to increasing knowledge in relation to materials, structures, plants and technologies that are more resilient to increasing temperatures and rainfall variability.

The first objective, which concerns the testing of materials, structures, plants and technologies more resilient to increasing temperatures and rainfall variability, is implemented into fifteen LF objectives: one from the Capoterra MMP's ER LF, eight from the Nuoro MMP's ER LF, five from the Selargius MMP's ER LF and one from the Sassari MMP's ER LF. With reference to the Capoterra LF, two actions, both connected to the LF objective, contribute to the achievement of the NPCCA objective in terms of transport network.

In reference to the Nuoro LF, twelve actions are connected to the eight LF objectives. With the exception of five LF objectives that are connected to a single action, the objectives "To restore areas currently hosting illegal buildings" and "To ensure the endowment of public services and facilities" are implemented through two actions each, while the objective "To enhance the historic center as a part of the city to be preserved and handed down to future generations in the most appropriate manner" is connected to five actions that contribute to the achievement of the NPCCA objective in relation to the transport network. With reference to the Selargius LF, the five objectives are implemented through a single action that contributes to the achievement of the NPCCA objective in terms of transport network. The action, concerning interventions aimed at mitigating and reducing the hydrogeological risk, is connected to three different LF objectives.

The only objective of the Sassari MMP's ER LF is linked to a single action that contributes to the achievement of the NPCCA objective in relation to the transport network.

The second objective concerning the integration of climate change risks into planning and design is implemented into nineteen objectives: one from the Capoterra MMP's ER LF, nine from the Nuoro MMP's ER LF, three from the Sassari MMP's ER LF, and six from the Selargius MMP's ER LF. With reference to the Capoterra LF, six actions, linked to a single LF objective, contribute to the achievement of the NPCCA objective in relation to the transport network. In reference to the Nuoro LF, thirteen actions contribute to the achievement of the NPCCA objective. In particular, with the exception of five LF objectives each connected to a single action, the LF objective "To enhance the historic center as a part of the city to be preserved and handed down to future generations in the most appropriate manner" is connected to five actions. The LF objectives "To ensure the endowment of public services and facilities," "To restore areas currently hosting

illegal buildings,” and “To enhance the area of the former powder mill in Prato Sardo,” are each connected to two actions contributing to the achievement of the NPCCA objective.

In addition, three actions (“Preparation of a landscape-oriented redevelopment plan”, “Conversion of the former railroad into a bicycle and pedestrian pathway”, and “Conversion of existing areas into parking areas”) refer each to two different LF objectives. With reference to the Sassari MMP’s ER LF, three actions contribute to the achievement of the NPCCA objective in relation to the transport network.

With the exception of one LF objective, the remaining two LF objectives “To encourage sustainable nature-based tourism” and “Protection and Conservation of Sites of Community Importance” relate to two actions. Furthermore, two out of three actions relate to two different LF objectives. With reference to the Selargius MMP’s ER LF, three actions contribute to the achievement of the NPCCA objective. With the exception of one action (“Redevelopment of the Is Corrias areas, the boundary areas with the municipality of Quartucciu, the boundary areas with the municipality of Monserrato”), which is connected to a single LF objective, the other two actions are connected, respectively, to three LF objectives in the case of the action “Interventions aimed at mitigating hydrogeological risks” and two LF objectives in the case of the action “Identification of the “Road of Parks” and concentration of areas handed over to the Municipality of Selargius through supplementary agreements pursuant to Law 241/90 within the areas “San Lussorio”, “Paluna” and “Santa Lucia””.

The third objective concerning the improvement of the effectiveness of monitoring, alerting and emergency intervention systems for transport services is implemented into a single LF objective related to the Capoterra MMP’s ER LF. In addition, six actions, linked to the MMP objective, contribute to the achievement of the NPCCA objective.

The fourth objective concerning the securing of the territory in relation to hydrogeological risk is implemented into seven LF objectives: three of the LF of Nuoro, and four of the LF of Selargius. With reference to the Nuoro LF, three actions contribute to the achievement of the NPCCA objective.

Apart from one action (“Functional reconversion of the Artillery Barracks into a university campus (Campus in the Green)”) which is connected to a single LF objective, the other two actions are both connected to two LF objectives. With reference to the Selargius MMP’s ER LF, four actions contribute to the achievement of the NPCCA objective. Except for one LF objective (“To protect the qualitative and quantitative status of surface and groundwater resources”) which is connected to a single action, the remaining three LF objectives are connected to all four LF actions.

## 4. Conclusions

In the construction of MMPs which implement CCA into their LFs, SEA is connoted as a process in which planning and evaluation are progressively integrated, leading to the identification of a system of objectives and operations aimed at their pursuit, which constitute a strategy.

Within this strategy, the evaluation of the impacts of choices, i.e., of plan actions, is aimed at incrementally refining this system in such a way as to arrive at an overall result that is identified as the best strategy with reference to the implementation of local development processes that are configured as expressions of the best compromise, i.e., the most effective integration, between the instances aimed at nature conservation and the protection of archaeological, historical and landscape resources, social equity, economic development and, certainly, the CCA (Lai and Zoppi, 2023).

Information and participation, on the part of public administrations vis-à-vis local communities, are, likewise, fundamental characteristics for the effectiveness of the evaluation and planning process, as factors that favor, in a relevant way, the recognition of their demands (Zoppi and Lai, 2010).

The methodological approach proposed and applied in this study could serve as a valuable tool to support decision-making processes related to spatial planning, and it has the potential to be applied in various European Union member states.

This adaptability is attributed to its alignment with national planning regulations based on legislation stemming from Directive 2001/42/CE. Within these regulatory frameworks, there is ample room for the incorporation of SEAs into the decision-making processes of MMPs, where they can seamlessly integrate questions and policies related to CCA.

The employed methodology may effectively help civil servants, practitioners, and local authorities in addressing the repercussions of changes in land cover and land use. From this perspective, the inclusion of CCA-related measures within MMPs' policies can serve as a foundation for steering local decision-making towards prevention or, at the very least, mitigation of damages caused by climate change impacts (Lai et al., 2020). Looking ahead, promising avenues for future research become apparent. One crucial focus should be on the implementation of SEAs for MMPs that entail legal provisions encompassing CCA-related activities within MMP implementation codes. Furthermore, an important area to explore is the role of local communities in shaping and executing environmental hazard management policies aimed at mitigating climate change impacts (Lai et al., 2021). These initiatives should be built upon the gradual enhancement of scientific, technical, and cultural knowledge within local societies regarding climate change, climate change impacts and CCA (Magnaghi, 2019). Within this conceptual framework, the evolving awareness within communities can be identified as a key driver of the qualitative enhancement of local spatial, environmental, and landscape assets. From this standpoint, policies related to CCA can be seamlessly integrated into planning practices undertaken by local governments, reflecting societies that fully grasp the significance of nature and natural resources in terms of enhancing quality of life (Magnaghi, 2020).

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## Authors' contributions

Federica Isola (F.I.), Sabrina Lai (S.L.), Federica Leone (F.L.) and Corrado Zoppi (C.Z.) collaboratively designed this study. C.Z. wrote sections 1, 2, 2.1, 2.1.1, 2.1.2, 2.1.3 and 6, and 2 in the Supplemental material. F.I. wrote Sections 3.2, and 1.2 in the Supplemental material. S.L. wrote Sections 2.2, 3.1, and 1.1 in the Supplemental material. F.L. wrote Sections 3.3, and 1.2 in the Supplemental material, available online at <https://drive.google.com/drive/folders/1Chml4fd7xogFUCMSd973gPnsgCS-KZdJ?usp=sharing>. Accessed February 18, 2024.

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## Images and tables sources

All images and tables have been elaborated by the Authors.

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