Strategic Environmental Assessment as a Tool to Embed Climate Change Adaptation in Urban Planning. The Case of Four Italian Cities

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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

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 [1], 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'" [1, p. 9], the SEA of the National Environmental Policy Plan 3 of the Netherlands, which places CCA among

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O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14818, pp. 275–292, 2024.
https://doi.org/10.1007/978-3-031-65273-8_18

the reference themes for identifying the structure and framework of administrative and technical competencies of the decision-making process [1, 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 [1, p. 153].

A very significant document is the Advisory Note on Environmental Assessment and CCA [2], 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 [2], 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. [3], 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 Gonzáles Del Campo et al. [4] 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 [5], "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" [6], which takes up and develops the contents of ENVIRONET's Advisory Note [2]. 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 [6, 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 [7]. 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 [8].

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) [9]. 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 [10].

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)[1] and the National Strategy for Adaptation to Climate Change of Italy (NSCCA)[2].

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[3]. The EUSCCA promotes, in this regard, the implementation of the conceptual and technical operational

[1] 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.

[2] 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.

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

framework of the EU Covenant of Mayors for Climate & Energy initiative[4], 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 [11–13]. 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.

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.

The paper is structured into five sections. The second section provides a brief description of the methodology used. In the third section, the results of the downscaling operation are presented, in relation to the reference areas most relevant to this operation. The fourth section provides recommendations for spatial planning policies. The concluding section highlights the prospects for the development of the research. The complete description of the methodology and the discussion on the results are reported in the full paper from which this study was excerpted[5].

2 Methods and Materials

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"[6], 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

[4] 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 2024/03/11.

[5] See the related acknowledgment at the end of this study.

[6] Retrieved from: https://www.mase.gov.it/sites/default/files/archivio/allegati/clima/PNACC_AllegatoIV_database_azioni.ods. Accessed 2024/03/11.

also taking into consideration the 18 NPCCA Reference Sectors[7] 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 methodological approach is implemented in relation to four case studies within the Sardinia Region, namely the municipalities of Capoterra, Nuoro, Sassari, and Selargius.

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

An extract from 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 Fig. 1 (third column), together with the objectives from which they descend within each LF (second column), and the NPPCA'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.

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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.

NPCCA goals	LF objectives	LF actions
To improve land management and maintenance.	NUORO – To regulate building expansion.	Analysis of the residential and service systems.
	NUORO – To restore areas currently hosting illegal buildings.	
To improve land management and maintenance.	SELARGIUS – To ensure soil conservation and protection.	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
	SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.	
	SELARGIUS – To prevent new hydrogeological hazards.	
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.	SASSARI – To prevent hydrogeological risks through appropriate land use regulations.	Identification of areas characterized by hydrogeological hazard and risk.
	SELARGIUS – To ensure soil conservation and protection.	
	SELARGIUS – To mitigate and reduce current hydrogeological risks in the municipality.	
	SELARGIUS – To prevent new hydrogeological hazards.	

Fig. 1. Extract from the goals related to hydrogeological instability contained in the NPPCA 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 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, all four MMPs develop strategies aimed at defining objectives and actions aimed at mitigating climate change negative impacts, and at adapting urban environments (see Fig. 2).

NPCCA's goals	LF objectives	LF actions
To improve thermal comfort and living quality in periurban areas, suburbs, historic centers, and public spaces.	CAPOTERRA – To redevelop and reorganize the consolidated Urban Poles (urban center, coastal area, and the settlement of Poggio dei Pini).	Qualification of the main urban settlement: consolidation of the urban fabric, endowment, completion and rationalization of technological and road networks, integration of residential and public services in accordance with territorial safety and specific studies.
To improve the efficiency of the water distribution system in periurban areas, suburbs, historic centers, and public spaces.		
To promote planning and design for hazard prevention and facilitating monitoring.		
To improve thermal comfort and living quality in periurban areas, suburbs, historic centers, and public spaces.	CAPOTERRA – To redevelop and reorganize the consolidated urban areas (urban center, coastal area, and the settlement of Poggio dei Pini).	Restoration and completion of the existing urban settlement.
To improve the efficiency of the water distribution system in periurban areas, suburbs, historic centers, and public spaces.		
To promote planning and design for hazard prevention and facilitating monitoring.		

Fig. 2. Extract from the goals related to Urban settlements contained in the NPPCA 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 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 [14].

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.

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 provides: i. in the first column, the NPPCA'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 NPPCA are associated; and, iii. in the third column, the actions that implement the LFs' objectives, integrate climate considerations, and contribute to addressing transportation network (see Fig. 3).

NPCCA goals	LF objectives	LF actions
To experiment with materials, structures, facilities, and technologies that are more resilient to increasing temperatures and rainfall variability.	CAPOTERRA –To regenerate and reorganize the consolidated urban areas (city center, Poggio dei Pini, coastal urban settlement), to be integrated within a unitary, organically articulated functional design.	Urban, road and environmental requalification of the structure of the coastal urban settlement in line with the landscape characteristics of the context as well as with the new structure that will take on with the construction of new road "SS 195" in order to guarantee adequate coastal accessibility and a rebalancing and compensation of the urban load of coastal settlements; provision of networks, including public and private services, to compensate for the strong existing imbalance between services and housing; enhancement of the connection systems between the different suburban realities.
To integrate climate change risks into planning and design process in order to promote resilience and adaptation.		
To improve the effectiveness of monitoring, warning and emergency response systems for transport services.		
To experiment with materials, structures, facilities, and technologies that are more resilient to increasing temperatures and rainfall variability.	CAPOTERRA –To regenerate and reorganize the consolidated urban areas (city center, Poggio dei Pini, coastal urban settlement), to be integrated within a unitary, organically articulated functional design.	Development of coastal land-use plans allowing for greater qualification and diversification of services.
To integrate climate change risks into planning and design process in order to promote resilience and adaptation.		
To improve the effectiveness of monitoring, warning and emergency response systems for transport services.		

Fig. 3. Extract from the goals related to transportation network contained in the NPPCA 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.

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 Policy Implications

Implications concerning planning policies aimed at integrating CCA into local planning processes, based on the LFs of the ERs of the SEAs of the MMPs of the four cities of Sardinia, are related to the plan actions arising from the implementation of the specific objectives.

An effective classification of the plan actions, that is, the operational part of the SEAs of the MMPs, which integrate CCA into the LFs, can be adequately represented by three general themes, as follows. First, the establishment or expansion of green areas, parks, outdoor recreation areas, forests, wooded areas and trees. Secondly, the appropriate management of the water resources regime of the municipal spatial contexts. Finally, greening operations referred to existing buildings or new developments.

Parks, forests and urban wooded areas significantly reduce surface temperature [15, 16]. According to a study by Armson et al. [17], the shading and evapotranspiration of wooded areas results in a 5–7 °C drop in temperature, while an article by Bowler et al. [18] estimates the temperature difference between urban parks and built-up areas at just under one degree. Urban wooded areas, through runoff mitigation, are, in addition, very effective in limiting vulnerability in relation to extreme weather events and, therefore, flooding events, which are particularly severe in urban areas characterized by a significant human presence. For example, Pataki et al. [19] estimate how built-up areas, whose soils

are made impermeable by urbanization, are characterized by runoff that falls within a range of 40–83% of rainfall, while in a wooded or forested urban area the phenomenon is about 13%.

With regard to planning policies referring to the construction or expansion of parks or wooded areas, the design profile is crucial for generating positive impacts in relation to heat waves, lowering temperatures, and for mitigating negative impacts of flood phenomena, including possible leakage of sewer lines [20]. There are, moreover, several studies available that estimate the economic impact of implementing these plan actions, although the outcomes are difficult to generalize (among many, [21, 22]).

The strengthening of ecosystems characterized by the presence of wooded and forested areas is based, in essence, on the protection of primary forests, the recovery of degraded forest systems, the sustainable management of wooded and forested areas, and tree plantings in contexts characterized by the presence of other ecosystems, such as, for example, urbanized areas or those dedicated to agricultural production: here, wooded areas operate effectively in relation to the mitigation of hydraulic and landslide risk, and the negative effects of heat waves.

Planning policies related to urban water resource management consist, fundamentally, of maintenance of riverbanks, and construction of retention basins, retention infrastructure, drainage, and release of water from the increasingly frequent extreme weather events, such as bioswales and rain gardens, and reservoirs [23]. Bioswales, rain gardens, and urban tree areas are also particularly effective vis-à-vis limiting pollution generated by sewage spills from pipes during extreme weather events [24]. Of great importance, as well, are plan actions aimed at re-permeabilizing soils, for example, by removing excess asphalt road covers, cleaning up riverbanks and riverbeds, and restoring tombed streams.

At the broad spatial scale, planning policies related to the relationships between CCA and water resource management generally have the function of regulating flood phenomena and consist of the re-functionalization and restoration of river courses and floodplains [7]. Floodplains and river belts provide the ecosystem service of mitigating the hardships that occur, in terms of water resource shortages, during periods of drought, as they promote, through drainage and water retention in the subsoil, the formation of water reservoirs, to be used, precisely, in the event of a shortage of the resource. Soil permeability allows, also, to decrease flood flows and the velocity of runoff, and to retain, at least partially, transported sediments: this function is also put in place by areas used for agricultural production, especially in valley bottoms [25]. Surface runoff, water retention, and natural drainage due to permeability, especially during flood events, are, also, facilitated by the effective management of forests and wooded areas, especially in or near river belts [26].

Regarding the management of transportation infrastructure, a relevant issue is the construction of roads, parking lots, pedestrian streets, and playgrounds whose permeable superstructures and pavements decrease runoff, especially during major storm events [24], and allow, as much as possible, its passage into underground aquifers, thereby promoting greater availability of the resource during drought periods, and, at the same time, decreasing the magnitude of flood flows, which often generate significantly negative

impacts in urban areas [27]. Porous pavements also enact an important filtering action that improves the quality of water that, through percolation, is stored underground [28].

As for the interventions on individual buildings that can be traced back to the plan actions arising from the SEAs that integrate CCA-related policies, these are identified with the implementation of green roofs, walls and facades [26]. The greening approach to buildings enables the implementation of effective stormwater management. According to a study by Ruangpan et al. [29], green roofs increase water retention and decrease, and/or delay stormwater runoff during particularly significant events by up to 70% and 96%, respectively, during peak rainfall. Green roofs, facades and walls are, also, very effective in improving comfort inside residences and decreasing energy demand for building interior air conditioning [30]. In addition, green surfaces, whether they are outdoors or on the building envelope, have greater reflective power of sunlight than artificial surfaces in the built environment, with a difference that falls, according to an article by Perini and Rosasco [31], in the range of 15–25%, with a very important impact on the mitigation of the urban heat island phenomenon.

Finally, it should be emphasized that, when defining the plan actions that are identified in the LFs of the ERs of the SEAs of the MMPs, the spillover effects of the implementation of these planning policies, i.e., the positive impacts that go beyond the integration of CCA into the LFs of the SEAs of the MMPs, should also be taken into account. FAO, for example, defines sustainable forest management as an evolving conceptual and technical category that aims to conserve and enhance the economic, social and environmental values of all forest types for the benefit of current and future generations, a category that consists, fundamentally, of making sure that the available productions, with reference to both timber and food, come from production systems that ensure an equitable intergenerational distribution of supply [32].

Forest management is, also, of great importance with reference to the abatement of concentrations of pollutants in water from spills generated by any productive activities, agricultural or industrial, that occur upstream [33]. The increase in the availability of the resource in subsurface water reservoirs, as a result of the substantial in hydraulic and naturalistic engineering works, implemented according to the conceptual references recalled above, constitutes an important positive impact regarding the management of water resources at the large territorial scale.

Natural forest ecosystems are reservoirs of biodiversity and constitute a relevant defense against the negative impacts of climate change [34]. The restoration of degraded forest and wooded areas and the planting of new forests are important references for the definition and implementation of effective land policies, including in economic terms, in relation to the balance between costs and benefits, both in the medium and long term [35].

Plan actions related to the micro-area scale also include those aimed at phytodepuration, such as the establishment of adequate riparian vegetation in river belts, retention and filtration wells, and artificial wetlands: these can be extremely effective in treating effluent before it is discharged into rivers [24]. In conclusion, it should be emphasized how a fundamental issue is represented by the inclusion, in prescriptive terms, of the plan actions concerning CCA, generated within the SEA processes, in the implementation codes of the MMPs.

One feasible approach to incorporate a set of rules explicitly linking CCA-related planning policies with the implementation of land-use regulations into the MMPs' statutory code is to establish project worksheets as prescriptive guidelines integrated within the planning code. These worksheets should provide detailed instructions on how to implement each identified plan action to address the specific objectives outlined in the MMPs' LFs. The use of such project worksheets is a well-established method, widely adopted in the planning regulations of various Italian cities, and extensively discussed in scientific and technical literature.

A notable example demonstrating the application of these project worksheets can be found in the Trieste Master Plan [36]. In this Master Plan, the project worksheet approach is used on a large spatial scale, particularly in areas earmarked for significant spatial transformations, urban regeneration zones, areas slated for urban renewal, and the creation of a new garden city. According to the Trieste Master Plan, project worksheets pertain to areas and subareas identified through the delineation of the relevant urban zones. Unless specified otherwise (with such specifications included in the worksheets), graphic elements are not prescriptive. However, the key project elements, quantitative parameters, implementation procedures, and land-use regulations are legally binding [36, p. 3].

These "key project elements" encompass quantitative parameters, urbanization efforts, and ecological criteria related to urban planning. These criteria are identified by factors such as permeability rates, tree and shrub densities, and should be integrated with the public service framework across different urban sectors, considering their endowments and planned interventions on existing settlements and expansion. The mandatory nature of these project worksheets concerning plan actions, as dictated by the Trieste Master Plan, necessitates a high level of technical detail to ensure the binding nature of the project rules, thereby ensuring the effective execution of these plans.

Nevertheless, the planning approach centered on project worksheets, which can be seamlessly integrated into standard spatial planning practices without the need for additional legislation, requires expertise not only in CCA-related technologies but also, perhaps most importantly, in financial aspects, project timelines, and the trained personnel essential for managing the operational phases of project implementation.

5 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 [16].

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 [37].

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 [15].

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 [38]. 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 [39].

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 [40].

Acknowledgments. F.I., S.L, F.L., and C.Z. collaboratively designed this study. F.I. wrote Sect. 3.2. S.L. wrote Sect. 3.1. F.L. wrote Sect. 3.3. C.Z. wrote Sects. 1, 2, 4, and 5. This study was carried out within the RETURN Extended Partnership and received funding from the European Union Next-Generation EU (National Recovery and Resilience Plan –NRRP, Mission 4, Component 2, Investment 1.3 –D.D. 1243 2/8/2022, PE0000005), with the financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 1409 published on 14.9.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title "Definition of a guidelines handbook to implement climate neutrality by improving ecosystem service effectiveness in rural and urban areas" – CUP F53D23010760001- Grant Assignment Decree No. 1378 adopted on September 1, 2023, by the Italian Ministry of Ministry of University and Research (MUR). And within the framework of the research project "Implementation and revision of the regional strategy for climate change adaptation (SRACC). Macro-Action 2, Mainstreaming of the SRACC spatial framework: governance and environmental assessment" (2021–2023), funded by the Autonomous Region of Sardinia. This article was excerpted from Isola F., Lai. S., Leone F., Zoppi C. (2024).

Integrating climate change adaptation into municipal masterplans through Strategic Environmental Assessment (SEA). A case study concerning Sardinia. TeMA – Journal of Land Use, Mobility and Environment, Special Issue 1.2024, 61–78. https://doi.org/10.6093/1970-9870/10438.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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