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Università degli Studi di Napoli Federico II

Via Toledo, 402
80 134 Napoli
tel. + 39 081 2538659
fax + 39 081 2538649
e-mail info.bdc@unina.it
www.bdc.unina.it

Direttore Responsabile: Luigi Fusco Girard
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Climate change adaptation and spatial planning: the mainstreaming concerning the regional context of Sardinia, Italy

Adattamento ai cambiamenti climatici e pianificazione del territorio: il mainstreaming relativo al contesto regionale della Sardegna, Italia

Federica Isola[a,*], Sabrina Lai[a], Federica Leone[a], Corrado Zoppi[a]

AUTHORS & ARTICLE INFO

[a] Department of Civil and Environmental Engineering, and Architecture, University of Cagliari, Italy

* Corresponding author
email: federica.isola@unica.it

ABSTRACT AND KEYWORDS

Climate change adaptation and spatial planning

The need to deal with and address the effects of climate change underscores the importance of identifying and implementing new spatial planning processes geared toward grafting these profiles into the definition and implementation of plan policies. With this in mind, it is particularly important to identify systems of goals and plan actions that outline and guide the integration of climate change adaptation into spatial plans, with particular reference to the local scale. In this contribution, we propose and implements a methodology, geared toward this integration, through the defining a programmatic framework for the construction of urban plans municipalities through strategic environmental assessment, as a pathway in which planning takes shape and structure, within the framework of the assessment, through a systemic strategy based on the overall and specific purposes of the planning framework, and a broad operational phase, based on systems of plan actions.

Keywords: climate change adaptation, spatial policies, strategic planning, strategic environmental assessment

Adattamento ai cambiamenti climatici e pianificazione del territorio

La necessità di trattare ed indirizzare gli effetti dei cambiamenti climatici sottolinea l'importanza di individuare ed implementare nuovi processi di pianificazione spaziale orientati ad innestare questi profili nella definizione e nell'attuazione delle politiche di piano. In quest'ottica, è particolarmente importante identificare sistemi di obiettivi ed azioni di piano che tratteggino e guidino l'integrazione dell'adattamento ai cambiamenti climatici nei piani territoriali, con particolare riferimento alla scala locale. In questo contributo, si propone e si attua una metodologia, orientata a quest'integrazione, attraverso la definizione di un quadro programmatico per la costruzione dei piani urbanistici comunali attraverso la valutazione ambientale strategica, quale percorso in cui la pianificazione prende forma e struttura, nell'ambito della valutazione, mediante una strategia sistemica fondata sulle finalità complessive e specifiche del quadro programmatico, e su un'ampia fase operativa, fondata su sistemi di azioni di piano.

Parole chiave: adattamento ai cambiamenti climatici, politiche territoriali, pianificazione strategica, valutazione ambientale strategica

1. Introduction

The methodological path defined and applied in this contribution aims at integrating climate change adaptation (CCA) into municipal planning processes. This path identifies the construction of municipal master plans (MMPs) with the process of strategic environmental assessment (SEA) of such plans, in which the plan is generated, endoprocessively, in the development of the assessment. SEA is, certainly, an important tool for integrating environmental considerations related to climate change adaptation into the strategic objectives of plans and programs. (De Montis et al., 2018). This construction is based on the declination, in the MMPs, through SEA, of the principle of sustainable development, according to the provisions of Legislative Decree 2006/152 (Art. 3-quater, and Art. 4, paragraph 4, letter a), in line with the conceptual approach of the Brundtland Report (WCED, 1987). This scientific and technical framework highlights important issues, both theoretical and applicative, with reference to local government spatial planning practices (Mininni & Migliaccio, 2011).

In general, the integration of 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 (Zamagni, 1995, Breuer et al., 2023). With regard, in particular, to spatial planning, this integration is not operationalized through measures identifiable in deterministic terms, but, rather, through practices that involve an open and continuous dialogue with local societies, based on mediation in relation to the instances and expectations they express, and ensuring, in this way, democracy into the process (González et al., 2023); 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 R., 2005). In relation to plan construction, 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; in this context, the effectiveness of SEA in the planning process is expressed in the change it produces in the plans in which it is applied (Rega et al., 2018). That is, a strategy, in which the evaluation of the impacts of choices, i.e., operations, is aimed at refining, incrementally, 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 or, the most effective integration, between the instances aimed at nature conservation and the protection of archaeological, historical and landscape resources, social equity and economic development (Brown & Thérivel, 2000; Kørnøv & Thissen, 2000). Information and participation, on the part of public administrations vis-à-vis local communities, are, likewise, key features for the effectiveness of the evaluation and planning process, since they are factors that promote, in a relevant way, the recognition of their demands (Thérivel et al., 1992). Local communities must be involved from the outset if public administrations are to open up. Trust must be the foundation of genuine public participation (Amalia & Diaconu, 2017).

In this article, the integration of CCA into the environmental report (ER) - the document that defines, together with the plan, the planning-assessment process, in accordance with the provisions of Legislative Decree 152/2006 (Art. 13) and, therefore, in the construction of the MMP - is divided into three phases, fundamentally oriented toward grafting the system of objectives of the National Plan for Adaptation to Climate Change (NPCCA)[1] into the planning-assessment process. It should be noted that the application of the methodology can be replicated with reference to any future updates of the NPCCA, whose strategic framework,

represented by the system of objectives of the updated version, would need to be incorporated.

The second section, firstly, describes the selection procedure used to choose municipalities for applying the methodological approach, and secondly, outlines the methodology's development, focusing on three phases. The first phase aims to identify, among the objectives of the NPCCA, those that can be associated with the processes of defining MMPs, thus having significant implications on land governance. The second stage is the construction of the system of specific MMP objectives to which the ER refers, that is, the construction of the logical framework (LF) of the MMP ER. In the third phase, the integration criteria identified in the first phase are used in the drafting of the ER for the construction of the MMP, as operational references to redefine the system of specific objectives and actions of the MMP, so that this system integrates the CCA into the overall strategy of the MMP.

The third section, showing the results of the implementation of the methodological approach defined in this article, is followed by discussion of these outcomes (Section 4) and highlighting some relevant policy implications (Section 5). The concluding part of Section 5 presents an important application of the results obtained for SEA-based spatial planning practice.

Moreover, in the concluding section, a Catalogue of the declination of the objectives of the NPCCA into specific objectives, plan actions and indicators related to the construction of the logical frameworks of the ERs of the SEA procedures of MMPs is presented and discussed as an illustrative reference for the integration of the CCA into the LFs of their ERs. This Catalogue is configured as a system of indications for the technical offices of municipalities and professionals who will have the task of applying the methodology for the construction of the ERs of the SEAs of MMPs. These are qualified and immediately operational indications, although non-binding and absolutely without a prescriptive character. The concluding section gives an account of the approach to identifying the structure of the Catalogue.

2. Materials and methods

This section is divided into two paragraphs. The first describes the procedure followed to select municipalities for the application of the methodological approach adopted for the definition of LFs integrating the CCA into the SEA process in which plans are produced, and some of their spatial characteristics.

The second section presents the development of the methodology, with reference to the three stages mentioned in the Introduction.

2.1 Selection of municipalities

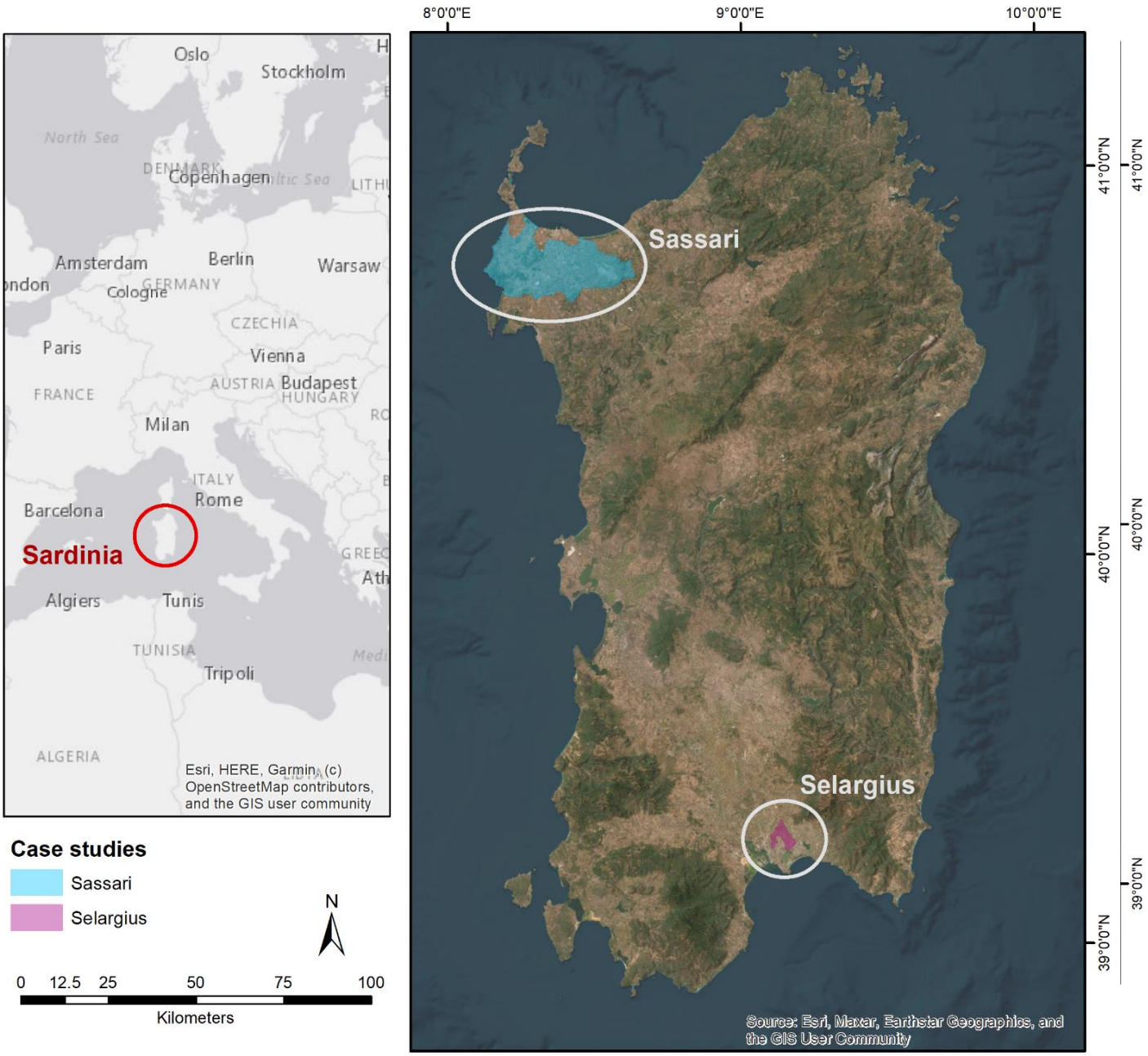
For the purpose of applying the methodology, the selection of MMPs to be analyzed was based on the following criteria:

- municipalities with an approved MMP in accordance with the Regional Landscape Plan (RLP) and the Hydrogeological Structure Master Plan (HSMP);
- municipalities with significant population for the Sardinian context;
- availability of plan and SEA documents on institutional websites.

For the first criterion, the registry of the monitoring of municipal planning instruments available on the Regional Geoportal[3], which led to the identification of about thirty municipalities with approved MMP in compliance with the HSMP and RLP, was used. The next criterion refers to population significance, which, using a threshold of 20,000 inhabitants, narrowed the number of municipalities to less than

ten. Finally, on the basis of the criterion of full availability of plan and SEA documents, four case studies were identified among the ten plans and fully analyzed; with respect to the purposes of this article, the application of the methodology is described in relation to two of them, i.e., the Municipality of Sassari and the Municipality of Selargius, belonging to the Metropolitan City of Cagliari (Figure 1).

Figure 1. Location of the municipalities of Sassari and Selargius in the regional context of Sardinia



Source: Authors' own elaboration on data from the Geoportal of the Autonomous Region of Sardinia[2]

Selargius and Sassari MMPs are the most representative and relevant in terms of CCA. Moreover, the two selected municipalities represent different realities. Sassari is the second most populous city in Sardinia and, therefore, considers a fairly complex system in terms of land-use planning. Selargius is representative of smaller municipalities.

2.2 Methodology

The proposed methodological approach is aimed at assessing the mainstreaming, i.e., the level of integration, of the CCA within spatial planning policies, with particular reference to the local scale. The assessment was carried out through the analysis of the plan documents of the MMPs of the two selected municipalities, including the environmental reports prepared as part of the SEA process with identification and reconstruction of their strategic framework of plan objectives and actions.

The method developed consists of three stages, namely: i. the selection of objectives and adaptation actions from the NPCCA relevant to land-use and urban planning; ii. the definition of the MMP's system of specific objectives through the structuring of the LF; iii. the analysis of the level of integration of CCA concepts into the MMPs.

With reference to letter 'i', the relevance of an objective of the NPCCA for land-use and urban planning is assessed taking into account two aspects as follows.

– Does the objective of the NPCCA represent an objective actually pursued by land-use and urban plans?
– Does the objective of the NPCCA deal with an issue that falls within the sphere of action of land-use and urban planning?

In the first stage, for the identification of the objectives and actions of CCA of interest to spatial and urban planning, reference was made to the "Database of Actions" contained in Annex IV of the NPCCA, in which adaptation actions are listed, distinguished by sector and objective, for each of which, in addition to some characteristics and evaluations, the relevant indicators of achievement and effectiveness are specified. Associated with the 18 sectors are 137 adaptation goals, of which 74 are evaluated as useful for the analysis of possible effects on land governance. In addition, the 137 objectives are associated, again in the same Annex IV, with 360 adaptation actions/measures, of which 251 are assessed as relevant to spatial and urban planning.

An excerpt of the overall list of objectives and actions referring to the sectors of the NPCCA, is shown, by way of example, in Table 1.

Table 1. Excerpt: sectors - objectives - actions contained in Annex IV of the NPCCA assessed as relevant to spatial and urban planning (labels refer to Annex IV)

NPCCA Sector	Objectives related to CCA		Actions implementing CCA	
Urban settlements	IU-1	Improve thermal comfort and living quality in peri-urban areas, suburbs, historic centers, and public spaces	IU007	Experimental adaptation interventions in peri-urban and supra-local areas of expertise
			IU015	Experimental and demonstration interventions for the implementation of urban green infrastructure
	IU-2	Improve the efficiency of the water supply system in peri-urban areas, suburbs, historic centers and public spaces	IU009	Experimental adaptation interventions in public space
			IU010	Experimental adaptation interventions at the building scale

The second stage involved the identification of spatial plans at the regional and local level, and the evaluation of the level of inclusion of CCA. For each of the two municipalities, SEA ERs and plan documents, such as general report and technical implementation rules, were analyzed in order to extrapolate the framework of general objectives, specific objectives and actions.

In the third stage, the logical framework approach was employed to analyze the level of integration of adaptation concepts into the MMPs. For each of the two cases, a general description of the MMP and the logical framework was carried out by

defining the process of identifying the plan objectives assessed as fully or partially consistent with the adaptation objectives of the NPCCA. The same process is followed for the evaluation of plan actions, for which examples of progress or effectiveness indicators are, in addition, presented, the latter potentially measuring contribution to adaptation goals. Next, each specific objective of the MMP was evaluated with regard to the level of integration of the previously chosen NPCCA objectives, and where integration was found to be partial, these objectives were reformulated in terms of adaptation. The same procedure was followed for the evaluation of the actions, making explicit how each action contributes to the achievement of the NPCCA objective to which it is linked through the specific objective, and, if necessary or appropriate, indicating any corrections or adjustments needed to raise the level of integration. Non-relevant actions were excluded from the evaluation.

The final result of the assessment is presented in the form of a matrix only comprising those rows for which relevance was found between the objectives of the NPCCA, the specific objectives of the plan and the plan actions related to them.

Table 2 shows the structure of the evaluation matrix conducted through the LF approach.

Table 2. Structure of the evaluation matrix

[a]	[b]	[c]	[d]	[e]	[f]	[g]
NPCCA objectives	**MMP specific objectives**	**Assessment of relevance between the goals of the NPCCA and the objectives of the MMP**	**(Possible re-) Formulation of the specific objectives of the MMP from the perspective of CCA**	**Plan actions related to the specific objectives and consistent with the goal of the NPCCA**	**Evaluation of the MMP's actions in relation to the objectives of the NPCCA**	**Indicators**
…	…	…	…	…	…	…
…	…	…	…	…	…	…
…	…	…	…	…	…	…

Table 3. Structure of the synthesis scheme

	Total number included in the MMP	**Unrelated (not included in the LF of the NPCCA)**	**Included in the LF**	**Fully consistent**	**Partially consistent**
Objectives [level]	…	…	…	…	…
Global scores [%]	…	…	…	…	…
Local scores [%]	…	…	…	…	…
	Total number included in the MMP	**Unrelated (not included in the LF of the NPCCA)**	**Included in the LF**	**Fully consistent**	**Partially consistent**
Actions [level]	…	…	…	…	…
Global scores [%]	…	…	…	…	…
Local scores [%]	…	…	…	…	…

For each MMP, further analysis was carried out to identify the indicators to be associated with the plan actions related to the specific objectives and consistent with the objective of the NPCCA. These indicators were extrapolated from the aforementioned Annex IV of the NPCCA in which, for each action/adaptation

measure, the relevant indicators of achievement and effectiveness are identified and, in case the indicators that can be associated with the NPCCA objective were not found to be evaluated useful for monitoring the MMP action, indicators were defined from scratch.

Finally, a quantitative summary table (Table 3) was developed for each MMP, showing the extent to which the specific objectives and actions included in the LF complement the adaptation objectives inferred from the NPCCA. In addition to a quantification, an overall score, calculated against the total number of specific objectives or actions in the plan, and a local score, calculated against the number of specific objectives or actions in the plan included in the LF, are proposed.

For both objectives and actions, local scores refer to the percentage against objectives/actions deemed relevant to the adaptation goals, while global scores refer to the entire set of objectives/actions in the MMP.

3. Results

The results for the two case studies, the Sassari and the Selargius MMPs, are given below.

3.1 Sassari

The Sassari MMP was adopted by City Council Resolution (CCR) No. 43 of 07/26/2012 and finally approved by Determination No. 3280/DG of 02/12/2014.

The main objective of the Sassari MMP is to address the malfunctioning of the urban system and the degradation of the environmental and landscape heritage that characterizes the municipal territory. To this end, it defines three general objectives, 20 specific objectives and 70 actions. The specific objectives refer to three macro-themes that echo the three general objectives and concern: i. the protection, preservation and redevelopment of the territory, both inland and coastal areas; ii. the redevelopment and enhancement of the existing city by promoting forms of densification of the settlement system and the preservation of peripheral semi-natural areas such as the olive grove crown surrounding the urban settlement; iii. the improvement of the mobility system, the promotion of sustainable economic and productive development.

From the comparison between each specific plan objective and each NPCCA objective, an evaluation matrix was defined, an excerpt of which is given in Table 4. In addition, Table 5 provides a summary of the assessment of the level of integration of the CCA into the objectives and actions of the Sassari MMP. Specifically, of the 20 specific objectives, four were rated as “not relevant” to each of the NPCCA’s objectives. Of the remaining 16 objectives, five were assessed as “fully consistent” and, as a result, did not require reformulation, while the 11 specific objectives assessed as “partially consistent” required reformulation (fourth column of Table 4). For example, Objective OBS01 “Protection and Conservation of Sites of Community Interest” has been reformulated so that these types of Natura 2000 sites are not considered as individual elements but as parts of a larger system consisting of both protected areas and the links between these areas, the so-called ecological corridors. The reformulated objective has the following form “Protection and conservation of Sites of Community Interest also with a view to building a system of protected areas.”

In terms of plan actions, a comparison between actions and objectives of the NPCCA shows partial consistency; in fact, for 21 of the 70 plan actions, no relevance to any

adaptation objective was found. Of the remaining 49, 22 were found to be "fully consistent", while 27 were rated "partially consistent." Among the partially consistent actions is, by way of example, Action AZ53, which provides for the connection of urban areas with the coastal arc of the Platamona coastline through the organization of the mobility system. It was assessed as "partially consistent" with respect to a single objective of the NPCCA, related to integrating climate change risks into planning and design towards resilience and adaptation. To ensure full consistency, it would be necessary, for example, for the action to introduce systems to encourage slow and sustainable mobility, as well as green interventions that are able to improve the integration of infrastructure into the surrounding landscape.

In terms of indicators, using as an example Action AZ41, which provides for the upgrading of roads both accessing the compact city and in the heart of the city and a system of residential parking facilities, including short-stay parking, only three indicators, which are simple to assess, monitor its progress and effectiveness with respect to the two objectives of the NPCCA to which it is linked:

– number of projects/interventions;
– km of roads with new drainage systems;
– absolute (km) and relative (%) increase in road drainage systems.

3.2 Selargius

The Selargius MMP has been adopted twice, by CCR No. 52 of 09/23/2015 and No. 1 of 01/19/2017. After final approval, which took place with Determination No. 941/DG of 05/25/2017, the plan underwent two variants, both concerning road issues.

The central objective of the MMP is to enhance, protect and manage the environmental, historical and settlement heritage, understood as an expression of local identity, also through integration of some actions of the Municipal Strategic Plan, including initiatives to involve and coordinate institutional, economic and social actors. There are seven general objectives of the MMP, each of which is articulated into a set of specific objectives, for a total of 25 specific objectives. For example, one of the specific objectives related to the general objective "Improving the urban, architectural and environmental landscape quality of the urban system" concerns "Redefining urban margins and safeguarding green corridors." The comparison between each specific objective of the Selargius MMP and each objective of the NPCCA, the summary outcomes of which are shown in Table 5, made it possible to populate an evaluation matrix, an excerpt of which is presented in Table 4.

For seven of the 25 specific objectives, non-relevance to all NPCCA objectives was found. Only four specific objectives were assessed as fully consistent with at least one NPCCA objective and the remaining 14 as "partially consistent"; for the latter, therefore, a reformulation was performed to integrate adaptation into the MMP strategy. For example, in the reformulation of the specific objective "Ensure soil conservation and protection," it was specified, on the one hand, that soil conservation and protection, originally referring exclusively to the natural and semi-natural areas of the Selargius spatial context, should also cover urbanized areas, and, on the other hand, that soil conservation and protection measures should ensure the permanence and functionality of the ecosystems present. The objective was, thus, revised as follows: "To ensure the conservation and protection of soil, including in urbanized areas, while guaranteeing the permanence and functionality of the ecosystems associated with it."

Table 4. Excerpt from the evaluation matrix referring to the Sassari and Selargius MMPs (labels refer to Annex IV of the NPCCA)

NPCCA objectives	MMP specific objectives	Assessment of relevance between the goals of the NPCCA and the objectives of the MMP	(Possible re-) Formulation of the specific objectives of the MMP from the perspective of CCA	Plan actions related to the specific objectives and consistent with the goal of the NPCCA	Evaluation of the MMP's actions in relation to the objectives of the NPCCA	Indicators
Sassari MMP						
DE-3 Preventing and mitigating salinization in coastal areas	OBS01 - Protection and conservation of Sites of Community Interest	DE-3, DI-4, EAI-4, EM-1, EM-2, ET-1, FO-1, FO-4, RI-1, TR-2, TU-2, ZC-1, ZC-2, ZC-4	OBS01 - Protection and conservation of Sites of Community Interest also with a view to building a system of protected areas	AZ01 - Construction of forested buffer strips (FBSs) at the edge of the adjacent agricultural system to control and abate major pollutant sources in the basin (Lake Baratz)	The establishment of buffer strips represents a form of protection and restoration of the wetland Lake Baratz	Number of funded projects Improvement of the ecological status of protected areas (networks)
TR-2 Integrating climate change risks into planning and design toward resilience and adaptation	OBS14 - Recovery of existing infrastructure for a new model of sustainable mobility	TR-2	OBS14 - Recovery of existing infrastructure for a new model of sustainable mobility	AZ53 - Connecting urban areas with the coastal arc of the Platamona coastline through the organization of the mobility system	Connecting urban areas with the coastal arc of the Platamona shoreline could be consistent with Objective TR-2 if it included encouragement of slow and sustainable mobility, as well as green interventions that also help improve the integration of infrastructure into the surrounding landscape	Reduction in incidents induced by extreme weather conditions Reduction in the number of new structures built in vulnerable areas
	OBS11 - Recovery of the historic center	DI-4, PC-1, TR-2	OBS11 - Rehabilitation of the historic center, including improving its ability to adapt to climate change	AZ41 - Redevelopment of streets both accessing the compact city and in the heart of the city and a residential parking system including short-stay parking	Road redevelopment can be consistent with Objective TR-2 if the design directions also contemplate the improvement of road drainage systems through the possible implementation of green interventions	Number of interventions km of roads with new drainage systems Absolute (km) and relative (%) increase in road drainage systems
Selargius MMP						
IU-1 Improve thermal comfort and living quality in peri-urban areas, suburbs, historic centers, and public spaces	OB_S1_2 - Fostering processes of reconfiguration and regeneration of urban planning, raising the quality of construction and public spaces and facilities	D1_4, EN_3, IU_1, IU_2, IU_3, PC_1, TU_2	OB_S1_2 Encourage processes of reconfiguration and regeneration of urban layout (built-up area and public spaces) in terms of water system, energy and quality of living	AZ03 - Definition of interventions and implementation methods that promote the redevelopment of the urban context and the existing built heritage	Redevelopment of the building stock and the urban environment results in improved quality of living and also improved thermal comfort, for example through the planting of tall trees that mitigate heat waves in the urban environment	Number of interventions Area (ha) redeveloped as urban green space Absolute (m^2) and relative (%) increase in public green area
				AZ07 - Identification of the infrastructural and environmental corridor of the "Road of parks" for the regeneration of the urban layout of the areas of St.	The "Road of parks" is an infrastructure designed with wide swaths of public green spaces that ensure the connection of all the green areas of the Selargius territory, allowing, through the same green areas, to be	Number of interventions Area (ha) redeveloped as urban green space Absolute (m^2) and relative (%) increase in public

NPCCA objectives	MMP specific objectives	Assessment of relevance between the goals of the NPCCA and the objectives of the MMP	(Possible re-) Formulation of the specific objectives of the MMP from the perspective of CCA	Plan actions related to the specific objectives and consistent with the goal of the NPCCA	Evaluation of the MMP's actions in relation to the objectives of the NPCCA	Indicators
				Lussorio, Paluna, St. Lucia and the improvement of the quality of public spaces and equipment	able to reach the countryside on foot and/or by bicycle. This intervention certainly improves the quality of living and thermal comfort	green area
TR-3 Securing the territory in relation to hydrogeological risk	OB_S1_3 - Encourage the rehabilitation of the city's peripheral areas, degraded areas, and agricultural areas	DI_4, EAI_1, ET_2, FO_1, IU_1, IU_2, IU_3, SA_1, TR_1, TR_2, TR_3, TU_2, ZC_1	OB_S1_3 - Encourage the rehabilitation of degraded areas in the suburbs, near waterways and in agricultural areas	AZ13 - Redevelopment of areas adjacent to State Road No. 554	Some areas in the vicinity of State Road No. 554 are subject to flooding, redevelopment of these areas could also be significant in relation to hydrogeological risk	Number of redevelopment interventions Extent of areas adjacent to State Road No. 554 usable as public spaces and usable/used as temporary stormwater collection areas

Fifty-two actions are linked to the 25 specific objectives; they appear, in general, to be linked to only one specific objective. There are, however, some cases where one action is linked to more than one objective. When comparing the actions of the MMP with the climate change adaptation objectives, only partial consistency emerges, which is well evidenced in the summary assessment in Table 5: slightly more than half of the plan actions were fully or partially consistent with the adaptation objectives, while for as many as 20 actions no relevance to any adaptation objective was found. Among those that are fully consistent is, by way of example, Action AZ07, which calls for the construction of the so-called "Road of parks," an infrastructure and environmental corridor equipped with large swaths of public green connecting municipal green areas. The action is fully consistent with the four objectives of the NPCCA to which it is linked, relating to improving thermal comfort and quality of living, improving the efficiency of the water supply system, increasing the permeability of soils, and finally reducing impacts through green infrastructure. Partially consistent actions include, as an example, Action AZ13, concerning the redevelopment of areas adjacent to State Road No. 554, which is only partially coherent with two objectives of the NPCCA. To ensure full consistency, it would be necessary, for example, to take into account the susceptibility of the areas to flooding phenomena and to introduce an ecosystem approach to improve spatial connectivity, given the caesura created by the highway.

Regarding indicators, using the aforementioned Action AZ07 as an example, only three indicators monitor its progress and effectiveness with respect to the four objectives of the NPCCA to which it is linked:

– number of funded projects;
– the area redeveloped as urban green, measured in hectares;
– the absolute (m^2) and relative (%) increase in the area of public green space.

Table 5. Summary table of the assessment of the level of integration of the CCA into the objectives and actions of the Sassari and Selargius MMPs

	Total number included in the MMP	Unrelated (not included in the LF of the NPCCA)	Included in the LF	Fully consistent	Partially consistent
Sassari MMP					
Objectives [level]	20	4	16	5	11
Global scores [%]		20.00%		25.00%	55.00%
Local scores [%]				31.25%	68.75%
Actions [level]	70	21	49	22	27
Global scores [%]		30.00%		31.43%	38.57%
Local scores [%]				44.90%	55.10%
Selargius MMP					
Objectives [level]	25	7	18	4	14
Global scores [%]		28.00%		16.00%	56.00%
Local scores [%]				22.22%	77.78%
Actions [level]	52	20	32	18	14
Global scores [%]		38.46%		36.62%	26.92%
Local scores [%]				56.25%	43.75%

4. Discussion

In each of the three parts of this section, the results presented in the previous section are discussed in the light of the outcomes of studies, available in the current literature, that deal, fully or in part, with similar issues, in order to highlight and motivate similarities and differences, and to bring out, especially in relation to the differences, open issues that call for further investigation, empirical analysis, and evaluation.

As described in subsection 2.2, the 18 sectors of the NPCCA include 137 adaptation goals, 74 of which are deemed relevant for analyzing potential impacts on land governance. These 137 goals are further linked, as detailed in Annex IV, to 360 adaptation actions or measures, of which 251 are considered pertinent to spatial and urban planning.

Among the sectors referenced in the NPCCA, those most prominent in the MMPs of the two Sardinian cities selected for the methodology discussed in Section 2 are hydrogeological instability, featuring 17 specific objectives and 38 planning actions; urban settlements, with 13 specific objectives and 23 planning actions, and transportation, with 19 specific objectives and 30 planning actions. This is the reason why the outcomes related to such sectors are analyzed and discussed in this study.

The discussion then develops in relation to the integration of CCA-related objectives and actions into the LFs of the analyzed MMPs' ERs, with reference to hydrological instability, the organization of urban settlements, and the structure of the transportation network.

4.1 Hydrological instability

The results from the analysis carried out on two MMP's ER LF highlight that, as far as landslide and flood hazard are concerned, three goals of the NPCCA have been integrated through the LFs' specific objectives and actions, either implicitly or explicitly. Commonly referred to as "mainstreaming" in the literature (Khailani & Perera, 2013; Newman, 2020; Santhia et al., 2018), such integration has been vastly advocated in the last decade. The integration, within planning tools, of measures aimed at preventing hydrogeological hazard and risk and minimizing damage from extreme events is regarded as a necessary complement to structural measures. While

the latter consist of expensive technical and engineering-based solutions such as dams, dikes, earth retention walls, which operate when the event occurs, the planning approach, together with institutional control and early-warning systems, is a "soft", or "non-structural" measure (Kang et al., 2009) that works primarily as a disaster prevention tool. Mainstreaming measures aimed at landslide and flood prevention and mitigation within spatial plans contrasts the increase in hydrogeological risks that normally accompanies development-oriented provisions contained in urban plans (Berke et al., 2015), reduces vulnerability and risks (Borowska-Stefańska et al., 2021; Norizan et al., 2021; van Herk et al., 2011), and, consequently, helps minimizing the need for structural interventions (Löschner & Nordbeck, 2020). Although institutional barriers to integration have been reported (Meng et al., 2022; van Herk, Zevenbergen, Rijke, et al., 2011), such as difficulty or unwillingness to innovate planning systems and tools (March, 2016), or mismatch between the time horizons of urban plans and flood management (van Herk, Zevenbergen, Rijke, et al., 2011), in some countries mainstreaming has become common practice (Kang et al., 2009; Khailani & Perera, 2013; Löschner & Nordbeck, 2020), or even mandatory (Junker, 2014; van Herk, Zevenbergen, Ashley, et al., 2011), especially as far as flood is concerned, whereas landslide consideration is less recorded in the literature. Strikingly, as reported by Mateos et al. (2020) who surveyed twenty-one European countries, a half of them do not have legal requirements in place for including landslide hazard consideration in spatial plans.

The NPCCA goal concerning hydrogeological instability related to knowledge improvements on critical geological and hydraulic issues is pursued by only one action, i.e., the preparation of studies, analyses, and maps of areas prone to landslides and flood in both Sassari and Selargius LFs, with a view to preventing hazards and risks and to grounding appropriate land-use regulations. The need for detailed analyses and maps concerning natural hazards, their probability of occurrence, and magnitude as a prerequisite measure to ground spatial decisions and policies is well established in literature. Morelli et al. (2012), for instance, who developed a geographic dataset concerning the Arno River, in Italy, argue that spatial information on critical spots can support planning processes and help prioritize interventions to counter flooding in Florence. In the same vein, Mihai et al. (2014) advocate the necessity of landslide susceptibility maps in support of mitigation-oriented planning, and, through the case study of Predeal, in Romania, show how susceptibility levels can be used to ground recommendations to be included in spatial plans and building codes. Likewise, Bernal et al. (2017) develop a five-level risk map for Manizales, in Colombia, and for each level they identify planning interventions, of which some are prescriptive requirements to prevent hazard and minimize impacts, and others depend on whether the area is already developed or not, and such identification of planning action is reputed by the authors as "more relevant than defining the level of hazard and risk" (p. 278).

From the above cited literature, it is quite evident that knowledge about hydrogeological instability and mapping of areas prone to floods and landslides traditionally feed into some sort of zoning scheme and planning or building regulations and restrictions, which leads to another NPCCA objective, concerning improved land management and maintenance.

The redesign of the zoning scheme pursues three different plan objectives, i.e., containment of the built environment, regulation of building expansion, development of a linear park equipped with services. Several examples of some sort of zonation stemming from hazard maps and analyses have been reported so far: from the inclusion of the "Waterstaat/Waterlopen" zoning overlay in the Nijmegen

plan, in the Netherlands, entailing a no-developing policy in flood-prone areas (Yu, 2020), to the "Blauzone Rheintal" legally binding regional plan of Vorarlberg, Austria, which grounds its no-building zoning system on the flood hazard designation map (Thaler et al., 2020), to the "Victoria Planning Provisions" that identify a so-called "Floodway zone", in Melbourne, Australia, where building is restricted based on flood modeling and mapping (Buxton et al., 2011). A different approach, albeit also reliant on hazard, vulnerability, or risk suitability maps, is that reported by Junker (2014) and in place in Norway, where, rather than no-development zones, so-called "special consideration zones" are identified, which do not ban any specific land use or function; rather, for such areas, specific conditions are included in the plan that are to be met prior to development or land-use conversion. This is somewhat similar to what Pottier et al. (2005) note with reference to England and Wales, where development in hazard areas can be allowed contingent upon the implementation of mitigation measures. To sum up, although with different approaches and to different extents, worldwide examples can be found that show a clear connection between spatial plans' zoning schemes and hydrogeological hazard assessment and mapping; aligning zoning schemes to mitigation of landslide and (mostly) flood hazard is, possibly, the most common and most effective non-structural climate adaptation measure in statutory land-use plans. Yet, it does not come without criticism: in the view of Maes et al. (2019), who explore the case of Limbe, in Cameroon, "success stories […] are rare", as "risk zonation leads to poor enforcement of the law and corruption" if used as a top-down policy to promote an authoritarian discourse and agenda on disaster management.

As for the actions related to the NPCCA goal planning and building regulations and restrictions, two actions contained in the Sassari's MMP belong to this group. The plan provides two main limitations to new development, which: i. in some residential and service areas can be allowed conditional upon the implementation of preliminary mitigation actions; ii. in private lots within new residential zones must be preceded by mandatory precautionary measures to mitigate flood hazard. Mitigation actions to be implemented prior to new development are not uncommon; they are often devised in relation to flood control and generally take place within public spaces (Worku, 2017), including for instance the designation of retention and runoff areas (Thaler et al., 2020) such as permeable public squares and pavements, multipurpose green areas, or urban forests, solutions that can either drain or store runoff water and precipitation in case of extreme events. Retention areas can, however, pose additional challenges to spatial planning, as land acquisition or relocation plans, whereby non compatible building, infrastructure and functions are moved out the hazard-prone areas, might be necessary (De Lotto et al., 2017; Kang et al., 2009; Mandarano, 2010). In such cases, statutory plans need to be complemented by other, more creative, tools, as for instance strategic planning approaches (De Lotto et al., 2017; Thaler et al., 2020), or transfer of development rights (Ward, 2013), neither of which was found in the analyzed MMPs. Moreover, the conditions set out in Selargius plan concern not public areas, but private lots, where flood protection measures to protect people, buildings, and properties, similar to the ones observed in the plan of Shah Alam, in Malaysia by Khailani & Perera (2013), must be implemented prior to construction. Contrary to what commonly happens with disaster mitigation measures, where public investment is the norm, the financial burden in the Selargius case is therefore borne by the landowner or the private developers.

Green areas are a powerful tool to mitigate natural hazards, as the presence of vegetation allows for the delivery of a range of ecosystem functions and services that

mitigate the impacts of both landslides and floods (Isola et al., 2023; Lai et al., 2021), including maintenance of porosity and permeability, water infiltration and groundwater recharge, evapotranspiration, soil retainment by the roots, hence supporting climate adaptation. Moreover, if such green areas are used for outdoor recreation and sports and are accessible to the local community, they also contribute to climate mitigation (Beery, 2019), as citizens will travel less by motorized modes of transports to reach their leisure destinations, therefore enabling reduction in greenhouse gas emissions.

Finally, the objective of seeking to improve knowledge on buildings and infrastructure as a prerequisite to strengthening their resilience is integrated via different types of actions and objectives within the analyzed MMP's ER LF. In Sassari, the action concerns buildings within the L'Argentiera mining village, built around 1870 and abandoned after 1963, when the lead and argentifer zinc mine was closed due to ore exhaustion[4]. Apart from the industrial buildings, the village comprises other factories, such as warehouses, workshops, sawmills, carpentries, but also the miners' and managers' houses, administrative offices, a cinema, and a church. A project for its reuse for tourism purposes has been around for over 15 years (Montis & Montis, 2008), and this kind of tourism-led regeneration is a shared vision for post-mining areas across the world (examples are provided, among many, by (Agustriani et al., 2020; Baihaqki, 2022; Hojka, 2023; Lamparska, 2019; Somoza-Medina & Monteserín-Abella, 2021). However, prior to any function repurposing within the land-use MMP, the issue of ensuring the structural stability of the buildings, as well as the absence of any landslide hazard within the mining tunnels themselves, need to be addressed. For mine site rehabilitation to take place, therefore, prior knowledge on the conditions of the buildings is needed to ensure stability and safety.

4.2 Urban settlements

From the analysis of the LFs of the ERs of the MMPs it is recognized that the status of urban settlements represents a very relevant issue in the definition of policies which implement CCA into the SEA processes. In urban settlements, greenhouse gas emissions are concentrated (Hoornweg et al., 2011), most of the areas characterized by sealed soils are found, and it is in cities that the practice of building culverted channels has developed, especially in the recent past, which dramatically increases flood risk(Kumar, 2021). Urban settlements represent, therefore, areas of great relevance for the identification of significant issues concerning CCA (MASE, 2023). This is highlighted, above all, in relation to the need to systematically integrate, in the processes of urban regeneration and expansion of settlement fabrics, measures aimed at improving the quality of life of local societies by increasing their resilience in relation to climate changes (MATTM, 2014). In the technical and legal framework of Italian spatial planning practice, these aspects are, ordinarily and typically, implemented into the MMPs (MATTM, 2014).

The analysis of the LFs of the ERs of the MMPs show that issues related to the relationship between CCA and urban settlements were appropriately taken into account. The NPCCA objective "Promote planning and design for hazard prevention" is implemented with particular reference to the flood events that affected the town in 2008 (Isola & Leone, 2019). The LF takes into account the rapid urbanization that has characterized this urban area in recent decades and represents a qualified attempt to orient planning policies toward CCA-oriented practices.

The set of plan actions aimed at the redevelopment of consolidated urban fabrics and peri-urban and rural areas, together with the provision of new technological and road

networks, fully pursue the NPCCA in terms of hazard prevention.

There are several examples of cities that have redefined their layout following disastrous events related to climate changes due to inadequate land-use planning. This is the case, for example, of Pelluhue, in the Central Maule Region of Chile (Ravazzi, 2013). In 2010, following the occurrence of an environmental disaster, a spatial planning strategy geared toward the redevelopment of peri-urban river areas at risk of flooding was defined. This strategic approach is based on analytical knowledge of the environmental dynamics that have characterized the territorial history, with particular reference to extreme events. It is an idea of redevelopment based on nature's reappropriation of the spaces that have been taken away from it by inadequately planned urbanization processes.

The plan actions related to the compensation of the urban load of coastal settlements and the provision of new public and private services are similar to those of the European Star-FLOOD Program (Ek et al., 2016). This tool defines a strategic system aimed at addressing flood risk with respect to eighteen urban regions, belonging to six European countries: Belgium, the United Kingdom, France, the Netherlands, Poland, and Sweden (Ek et al., 2016).

Relative to the NPCCA objective "Improve thermal comfort and living quality in urban and peri-urban areas," in all the LFs analyzed it is evident that it is fully integrated through the formulation of plan actions aimed at the energy adaptation and efficiency of public and private buildings and the green adjustment of public spaces. These two types of actions are based on the assumption that the relationship between urbanized areas and thermal variations in the urban environment (CNR, 2018) is a key element in the quality of life in the city.

In particular, greening measures implemented into building redevelopment is a key operational approach for the urban area in terms of sustainability and resilience (Mari, 2023). In particular, the greening adjustment approach is recognizable in the land redevelopment and enhancement strategy, which defines a set of plan actions aimed at converting public spaces to green. These are configured, among other things, as a heat wave mitigation tool (Zou & Zhang, 2021) in a city that, in the summer months, is significantly characterized by this phenomenon.

The same condition characterizes the operational strategy of the LF of the ER of the Selargius MMP, which, in order to respond to the need to ensure an adequate endowment of public areas for services and greenery, provides for the allocation of public areas owned by administrations other than the city administration for these urban functions (Roshan et al., 2022).

In the Selargius case, it is essential to verify the thermal response of the systems of plan actions on the urban territory. A useful methodological approach to this verification is proposed by Casu & Lai (2021) in relation to an urban redevelopment program conducted, in the years between 2015 and 2019, by the Municipality of Lisbon. In the study, an assessment of the thermal response of urban open spaces is proposed through the analysis of changes in an indicator related to the land surface temperature. A further approach to the identification of thermal response is proposed in an experiment conducted by Magliocco & Perini (2014) on the simulation of environmental comfort microclimatic effects related to the increase of vegetation in the urban context. The experimentation covered the Italian Cities of Milan, Genoa and Rome, and was carried out using the three-dimensional microclimate model ENVI_met. The reduction in temperatures as a result of increased amount of vegetation is evident in all cases analyzed, even in the vicinity of green areas, consistent with a study by Hegazy & Qurnfulah (2020). This result highlights how the actions of the analyzed LFs can effectively support the achievement of the

NPCCA objective concerning the improvement of thermal comfort and living quality in urban and periurban areas.

With reference to the NPCCA objective "Improve the efficiency of the water distribution system in urban and periurban areas", the LFs implement this objective and there are numerous actions that pursue it. As for the LF of the ER of the Selargius MMP, one of the plan actions associated with the objective involves the implementation of measures to prevent environmental damage in residential expansion areas and the preparation of technical guidelines for the management of the integrated water cycle. The measures concern the application of the principle of hydraulic invariance in new urbanizations, with the implementation of lamination tanks and stormwater collection tanks in individual lots. According to Napolitano (2019), these actions can be traced back to the vision of water-sensitive cities, in which new technological approaches to the design and management of the integrated water cycle are being tested, both in the consolidated urban fabric and in the periurban sphere, coupled with new regulatory devices that formally implement these approaches in the practice of spatial planning. In a recent study by Berteni et al. (2021), a comparison is proposed between the regulatory and technical devices of Italian regional administrations regarding the calculation of storage volumes required to ensure hydraulic and hydrological invariance. A comparative analysis of the devices in place in the Emilia-Romagna and Lombardy Regions is developed. The study shows that the regulatory and technical apparatuses adopted by the two regional administrations are quite different, although they show significant similarities. Differences are evident in relation to the use of nature-based solutions for discharge containment and drainage systems (Ciocca, 2021).

4.3 Transportation network

The results of the analysis conducted on the LFs of the ERs of the MMPs show how four NPCCA objectives were integrated through the specific objectives and actions of the LFs of the ERs of the MMPs in an implicit and explicit way in relation to the transport network.

The number of the LFs objectives (22 objectives) and actions (29 actions) that integrate the NPCCA objectives is not surprising, since the transport sector is a pivotal system within society. Transport network is closely connected to many other sectors such as, for example, hydrogeological instability, air, water system, urban settlements, industry, tourism, and energy.

Analyzing the vulnerability of the transport system as a whole is not easy (MASE, 2023). The impacts of climate change on the transport and infrastructure sector are mainly due to rising temperatures, changes in rainfall patterns and rising sea levels. These phenomena entail possible consequences in terms of material leakage of road (asphalt) and rail (track) infrastructure, flooding of underground infrastructure, as well as potential problems for road and rail infrastructure located close to coastlines and for port infrastructure (Piattaforma Nazionale Adattamento Cambiamenti Climatici, n.d.). As regards the transport sector, the current direct economic impact associated with extreme climate events is estimated at EUR 0.15 billion per year, which could grow by about 1900% by 2040-2070 (MIMS, 2022).

Despite the importance of the transport sector, CCA is not yet fully integrated into transport planning and decision-making practices. In some countries (Denmark, Finland, and United Kingdom), sectoral CCA strategies or programs are developed. In other countries (Hungary, Germany, and Sweden), general objectives concerning CCA have been introduced within national transport plans, while elsewhere (France and Spain) specific actions are defined in compliance with national adaptation plans

(EEA, 2014).

The results of the analysis show that the four NPCCA objectives relate to different aspects of integrating climate change adaptation into the transport sector. The first objective focuses on the testing of materials, structures, facilities, and technologies that make the transport system more resilient to rising temperatures and variable rainfall. The second objective considers the integration of climate change risks into planning and design to improve resilience and adaptation. The third objective concerns the improvement of the effectiveness of monitoring, warning, and emergency response systems for transport services. Finally, the fourth objective is related to the securing of the territory in relation to hydrogeological risk. The four NPCCA objectives are pursued through numerous actions, some of which refer to more than one NPCCA objective. The actions can be grouped into three different themes, ranging from the territorial dimension to the local scale of the single intervention.

The first theme concerns the planning and programming of interventions, and it comprises actions that refer to the definition of strategies, measures, and guidelines. This type of action relates to all four NPCCA objectives. Some examples of these actions are "Preparation of a landscape-oriented redevelopment plan" (first and second NPCCA objectives), "Interventions aimed at mitigating hydrogeological risks" (first, second and fourth NPCCA objectives), "Development of coastal land-use plans allowing for greater qualification and diversification of services" (first, second and third NPCCA objectives), and "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" (fourth NPCCA objective). With reference to the definition of guidelines for sustainable water cycle management, some examples in the literature and in planning practices exist. In 2018, the Municipality of Bologna drew up guidelines for the adoption of urban drainage techniques based on the soft engineering approach. Within the guidelines, data sheets are proposed concerning ten different solutions (rainwater harvesting, detention basins, tree box filter, etc.). For each data sheet, a description of the proposed technical solution, the components of the system and the limitations of its use are provided, as well as dimensional and design guidelines (Comune di Bologna, 2018). Butler et al. (2010) provide guidelines on sustainable water cycle management in new settlements. The guidelines represent one of the outputs of the WaND Project, which was funded by the UK Engineering & Physical Sciences Research Council (EPSRC) between 2003 and 2007 and was carried out by the Centre for Water Systems at the University of Exeter. The guidelines were designed to suggest tools, technologies and approaches related to the sustainable management of the water cycle in new settlements at different scales.

The second theme concerns the redevelopment and/or restoration of certain areas within cities. This type of action contributes to the pursuit of three NPCCA objectives and does not find any correspondence in the objective relating to making the territory safe against hydrogeological risk. The second theme refers to a set of actions that are implemented at the urban scale, including the restoration and completion of the existing urban settlement, the consolidation of the urban fabric and the rationalization of the technological and road networks, the urban, road and environmental requalification of the coastal urban settlements, and the elaboration of specific analyses concerning the residential and service system. According to a study by Deweerdt & Fabre (2022), who discuss the role of land-use planning in mitigating the effects of climate change in the transport sector, by defining the spatial

distribution of the transport network, land use influences the urban form of cities and the travel demand. Promoting efficient use of the urban environment may decrease travel distances and encourage more sustainable transport systems (Dulal et al., 2011; Holz-Rau & Scheiner, 2019), reducing reliance on the private car, traffic congestion and counteracting urban sprawl (Miller & Spoolman, 2015). For example, actions could involve the allocation of part of the roads for bus lanes, which would thus favor the use of public transport (Banister, 2011). In terms of actions related to a reorganization and/or completion of urban settlement, one useful tool is oriented towards localizing and centralizing population around major public transport nodes, so-called transit-oriented developments (TODs). TODs also aim to transform transport infrastructure in order to make transport network efficient, polycentric and multi-destination (Kenworthy, 2018; McLeod et al., 2017). For instance, over the past 60 years Stockholm has become a multi-centered metropolis with a low level of car dependency, due to the concentration of most new urban settlements in high-density agglomerations around railway stations (Dulal et al., 2011).

The third issue concerns individual interventions at the local scale. This typology of actions contributes to the integration of three NPCCA objectives. In general, actions refer to the construction of new stretches of the road network, the realization of car parks, the conversion of a railway section into a bicycle and pedestrian pathway, and the realization of green routes (bicycle and pedestrian). This typology of actions belongs to the category of hard adaptation measures, i.e., concrete actions that refer to structural transformations to reduce damage such as the protection of road corridors or the redesign of road locations (IRF, 2019). de Abreu et al. (2022) provide several examples of hard adaptation measures in relation to the type of risk to which the road infrastructure is subject. In relation to the risk associated with heat waves, the use of cool pavements decreases the sensible heat released from pavements into the atmosphere. This decrease can be achieved through various techniques, such as increasing the albedo of road surfaces by using resin-based pavements or the use of additives such as fly ash and slag cement, or by increasing the apparent heat capacity of road pavements using phase change materials that allow for lower surface temperatures during the day (Akbari et al., 2015). The use of vegetation in the vicinity of transport networks makes it possible to mitigate the effects of heat waves (Estrada et al., 2017). A study by Marando et al. (2019) analyzes the cooling capacity of some elements of a green infrastructure, including street trees, by taking the street trees in Viale Mazzini in Rome as a case study. The study highlights how street trees allow surface temperatures to be 1.3 °C lower than the surrounding areas and show that their influence extends up to 30 meters from the trees line. In relation to the risk associated with heavy rainfall, some solutions include the use of drainage pavements in order to increase runoff capacity (Pregnolato et al., 2017), increasing the curvature of the road surface to accelerate surface water runoff (Regmi & Hanaoka, 2011), and the use of nature-based solutions and other types of green infrastructure enabling water infiltration and peak flow reduction (Lallemant et al., 2021).

5. 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, 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 (Lai et al., 2020; Lai & Zoppi, 2023; EEA, 2020). According to a study by Armson et al. (2012), the shading and evapotranspiration of wooded areas results in a 5-7 °C drop in temperature, while an article by Bowler et al. (2010) 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. (2011) estimate how built-up areas, whose soils are made impermeable by urbanization, are characterized by runoff that falls within a range of 40-83 percent of rainfall, while in a wooded or forested urban area the phenomenon is about 13 percent.

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 (Berland & Hopton, 2014). 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, Calfapietra, 2020; Roy et al., 2012).

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 (UNaLab, 2019). 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 (Wild, 2020). 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 (Francini et al., 2021). 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 (Reberski et al., 2017). 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 (EEA, 2021).

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 (Wild, 2020), 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 (Du et al., 2019). Porous pavements also enact an important filtering action that improves the quality of water that, through percolation, is stored underground (Depietri & McPhearson, 2017).

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 (EEA, 2021).The greening approach to buildings enables the implementation of effective stormwater management. According to a study by Ruangpan et al. (2020), green roofs increase water retention and decrease, and/or delay stormwater runoff during particularly significant events by up to 70 percent and 96 percent, 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 (Francis & Jensen, 2017). 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 & Rosasco (2013), 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 (FAO, 2020).

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 (Mysiak et al., 2019). 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 (Forest Europe, 2015). 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 (Mansourian et al., 2019).

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 (Wild, 2020).

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 (Regione Autonoma Friuli-Venezia Giulia - Comune di Trieste, 2018). 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 realization 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 (ibid., 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.

6. Conclusions

The methodological approach identifies SEA and MMPs as intrinsically linked, and configures the production of the plan as ontologically integrated into the evaluation process, so much so that there is no plan, hence no MMP, without SEA (Zoppi & Lai, 2014), since the strategic and operational framework of the plan is built within SEA (Kørnøv & Thissen, 2000; Curreli & Zoppi, 2021).

Thus, concrete application is given to the sustainability paradigm in the SEA process, in which the plan strategy is progressively improved, also with the involvement of

local societies, with a continuous verification between the system of objectives and the system of operational measures, which continues, more effectively, in the implementation phases. Evaluation and planning are aimed at implementing a holistic approach to local development, in the strategy and implementation of which the protection of nature and archaeological, historical and landscape resources, social equity and economic development are integrated, in a virtuous way (Zoppi, 2018).

According to this conceptual key, the MMP is constructed through an SEA process in which the strategy is based on the integration of the CCA, and in which, therefore, the implementing measures or actions of the plan, are aimed at operationalizing adaptation.

The Catalogue, mentioned in the Introduction, of which a brief excerpt concerning the NPCCA Reference Area "Terrestrial Ecosystems" is presented in Table 6. It shows the declination of the objectives of the NPCCA defined, in tabular form, in Annex IV of the NPCCA.

Such document is taken as a reference because it offers an LF, analytical and systematic, of detail and easily allows for the declination of the CCA in different fields of planning and strategic programming and implementation of public policies, among which is the profile of urban and territorial planning and design, in which the SEA of the MMP is placed.

The methodological approach with which the Catalogue in Table 6 is constructed can be effectively taken in relation to the LF of the NPCCA and constitutes a fundamental reference for integrating CCA issues into the SEA procedures of MMPs, and, in this way, stand as a structural operational pillar of the regional CCA strategy.

It is emphasized, in other words, how this Catalogue is to be used in methodological terms, beyond, therefore, the drafting of the LF of the NPCCA, the most recent version of which is assumed here.

The NPCCA LF is divided into objectives concerning 18 reference sectors (Aquaculture; Agriculture and Food Production; Desertification, Land Degradation and Drought; Geological, Hydrological and Hydraulic Disruption; 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).

As discussed in this article, a part of the NPCCA goals is relevant to MMPs, and are implemented, in MMPs, through their declinations, which are inherently non-exhaustive, as each MMP implements the NPCCA goals in relation to the specificities of the municipal area to which it refers.

Table 6. Excerpt from the Catalogue of the declination of the objectives of the NPCCA

NPCCA objectives	MMP specific objectives	Plan actions related to the specific objectives and consistent with the goal of the NPCCA	Indicators
TERRESTRIAL ECOSYSTEMS			
Adapt ecological corridors and protected areas to changing	SASSARI - Protection and conservation of Sites of Community Interest	Construction of forested buffer strips (FBSs) at the edge of the adjacent agricultural system to control and abate major pollutant sources in the basin (Lake Baratz)	Number of funded projects Improvement of the ecological status of protected areas (networks)

NPCCA objectives	MMP specific objectives	Plan actions related to the specific objectives and consistent with the goal of the NPCCA	Indicators
species ranges	SASSARI - Protection and Conservation of Sites of Community Interest SASSARI - Encouragement of environmentally sustainable nature tourism	Realization of a strip with ecotonal function inserted between the agricultural ecosystem and the edges of the lake system (Lake Baratz)	Number of funded projects Improvement of the ecological status of protected areas (networks)
		Integrated recovery of the environmental resource system of the dunes, wetlands, pine forest of Platamona (Wetland of Platamona)	
		Conservation and enhancement of Posidonia oceanica areas and enhancement of the Platamona juniper and pine forest (Wetland of Platamona)	
		Establishment of interface filter areas between the agricultural area and the wetland with ecotonal function to combat eutrophication (Wetland of Platamona)	
		Establishment of interface filter areas between the agricultural area and the wetland with ecotonal function (Wetland of Pilo)	
		Preservation and protection of the most sensitive areas related to the presence of avifauna (Wetland of Pilo)	
		Construction of forested buffer strips (FBSs) at the edge of the adjacent agricultural system to control and abate major pollutant sources in the basin (Lake Baratz)	
	SASSARI - Encouragement of environmentally sustainable nature tourism SASSARI - Redevelopment and environmental landscape protection of the Nurra hill system and safeguarding the underground water resource.	Realization of a strip with ecotonal function inserted between the agricultural ecosystem and the edges of the lake system (Lake Baratz)	Number of funded projects Improvement of the ecological status of protected areas (networks)
		Integrated recovery of the environmental resource system of the dunes, wetlands, pine forest of Platamona (Wetland of Platamona)	
		Conservation and enhancement of Posidonia oceanica areas and enhancement of the Platamona juniper and pine forest (Wetland of Platamona)	
		Establishment of interface filter areas between the agricultural area and the wetland with ecotonal function to combat eutrophication (Wetland of Platamona)	
		Establishment of interface filter areas between the agricultural area and the wetland with ecotonal function (Wetland of Pilo)	
		Preservation and protection of the most sensitive areas related to the presence of avifauna (Wetland of Pilo)	
		Protection of vegetation cover (garrigue, scrub, forest)	
Countering biodiversity loss and alien species invasion and adapting ecological corridors and protected areas to changing species ranges	SELARGIUS - Encouraging the rehabilitation of the city's peripheral areas, degraded areas and agricultural areas	Redevelopment of areas adjacent to State Road No. 554	Number of interventions for the conservation of genetic resources Increase in the number of forest species
	SELARGIUS - Encouraging the rehabilitation of the city's peripheral areas, degraded areas, and agricultural areas SELARGIUS - Redefining urban margins and safeguarding green corridors.	Unified study of green areas in expansion areas with planting of plants close to state roads	Increase in the number of forest species
		Provision of the "Road of Parks" and concentration of disposal areas acquired through supplementary agreements under Law 241/90 within the wedge San Lussorio, Paluna, Santa Lucia	Extension of green areas along the "Park Road" Increase in the number of plant species
	SELARGIUS - Redefining urban margins and safeguarding green	Provision of compensation mechanisms to ensure continuity of the Riu Nou river corridor	Monitoring of the ecological status of the water body

NPCCA objectives	MMP specific objectives	Plan actions related to the specific objectives and consistent with the goal of the NPCCA	Indicators
	corridors. SELARGIUS - Pursuing an environmental policy aimed at increasing the quantity and quality of green spaces in the urban and suburban context	Concentration of areas for services acquired for the development of public parks	Number of interventions for the conservation of genetic resources Increase in the number of forest species
	SELARGIUS - Recognize and protect the morphological features of the Selargius municipal area as landscape assets and dominant elements in the local context	Establishment of standards to ensure the preservation and protection of physical environmental landscape and natural interest assets	Number of interventions for the conservation of genetic resources Increase in the number of forest species
	SELARGIUS - Recognize and protect the quali-quantitative characters of the vegetation cover, identified as landscape assets of naturalistic value	Identification and delimitation of the physical environmental landscape assets and natural interest present within the municipal territory	Number of genetic resource conservation interventions

The Catalogue proposes, in relation to the experimental research carried out with reference to the MMPs of Capoterra, Selargius, Nuoro and Sassari - the results of which, in this article, have been discussed for Sassari and Selargius - the declination of the objectives of the NPCCA, articulated in the sectors with which they are associated in the aforementioned Annex IV. For each of the NPCCA objectives identified as relevant to the selected MMPs, a system of specific objectives, plan actions and plan action implementation indicators is defined, identifying the Catalogue, which stands as a working document of useful reference, methodological and technical-applicative, for the integration of the CCA in the drafting of the ERs of the SEA procedures of the MMPs.

The sectors of objectives of the NPCCA appear in the rows, while the objectives of the NPCCA are shown in the first column. The second column shows the specific Objectives of the MMPs that constitute its declination, with reference to the MMPs of the municipalities subject to the experimentation. The third column shows the plan actions that, in the territorial contexts of the municipalities, the MMPs plan for the implementation of the specific objectives, while, in the fourth column, the implementation indicators are highlighted, taken directly from the NPCCA, referring to the plan actions.

It should be emphasized how the Catalogue constitutes a methodological and technical-applicative aid to the integration of the CCA in the drafting of the ERs of MMPs, and how it presupposes ad hoc use in each specific case, with the development of careful and detailed reasoning for the declination of the objectives of the NPCCA into the specific objectives of the MMP, for the identification of the plan actions related to the implementation of these objectives and for the identification of the related indicators.

The issue of indicators needs to be carefully analyzed when drafting the ER, as very few of the indicators proposed by the NPCCA are available at the municipal level: realistically, the SEA monitoring plan in itinere will have to define a system of indicators available at the municipal level from certified sources, or populated, by the municipality, with ad hoc surveys planned in time, in as timely, simple and financially sustainable a manner as possible.

The Catalogue stands as an important outcome of the integration of CCA into municipal planning, as it configures, in operational terms, a qualified example of the

application of the methodology, proposed in this contribution, which identifies the construction of the plan with the evaluation process, and an effective reference for its export to other local contexts, both domestic and foreign.

Notes

1. https://www.mase.gov.it/notizie/clima-approvato-il-piano-nazionale-di-adattamento-ai-cambiamenti-climatici (last accessed: 19 July 2024).
2. https://www.sardegnageoportale.it/ (last accessed: 19 July 2024).
3. The thematic navigator is available at https://www.sardegnageoportale.it/webgis2/sardegnamappe/?map=monitoraggio_strumenti_urbanistici (last accessed: 19 July 2024). Data extrapolation from the attribute table of the shapefile "Monitoraggio strumenti urbanistici comunali, PUL, PP centri matrice e riperimetrazioni centri matrice" ["Monitoring municipal urban planning instruments, PULs, PP matrix centers and matrix center reapportionments"] (https://webgis2.regione.sardegna.it/geonetwork/srv/ita/catalog.search#/metadata/R_SARDEG:4c48fe46-1014-4846-ae83-39c3be986b99, last accessed: 19 July 2024) was carried out in December 2021.
4. Sassari, Miniera dell'Argentiera. Retrieved from: https://www.sardegnacultura.it/j/v/253?v=2&c=2488&t=1&s=21538 (last accessed: 19 July 2024).

Author Contributions

Collaboration Group Member: the article is the result of the joint research of the authors. Writing - Original draft preparation, Review & Editing: The first and second sections were jointly drafted. Sabrina Lai and Federica Leone were jointly responsible for writing sections 3.1 and 3.2, Sabrina Lai was responsible for section 4.1, Federica Isola for section 4.2, Federica Leone for section 4.3, Corrado Zoppi for sections 5, and Federica Isola and Corrado Zoppi were jointly responsible for writing section 6.

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Conflicts of Interest

The authors declare no conflict of interest.

Originality

The authors declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere, in English or any other language. The manuscript has been read and approved by all named authors and there are no other persons who satisfied the criteria for authorship but are not listed. The authors also declare to have obtained the permission to reproduce in this manuscript any text, illustrations, charts, tables, photographs, or other material from previously published sources (journals, books, websites, etc).

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