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Mainstreaming Climate Change Adaptation into Sectoral Plans: An Assessment Based on the Logical Framework Approach

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Abstract: Although climate change adaptation (CCA) and spatial planning are relevant to promoting climate resilience, Italy shows a certain lack of studies focused on the coherence between national CCA objectives and sectoral plans. We aim to investigate such a research gap and propose and apply a logical framework approach (LFA)-based method to assess the coherence of sectoral plans adopted in Sardinia (Italy) with the missions of the Italian National Climate Change Adaptation Plan (NCCAP). We apply LFA to analytically scrutinize sectoral plans by reconstructing their strategic framework—including objectives and actions—and comparing them to the CCA objectives established by the NCCAP. The purpose is to provide the regional administrations with a methodological approach and tangible findings, suggesting the need for updating plans lacking CCA contents and contributing to the drafting or updating of the regional strategy for CCA. The method adopted in this study allowed us to identify plan objectives and actions that fully or partially integrate NCCAP objectives. Then, plans partially (or not at all) consistent with the NCCAP can be integrated with CCA contents. This is relevant to promoting climate resilience issues in plans that have clear effects in terms of spatial, landscape, and urban planning, according to different governance levels.

Keywords: climate change adaptation governance; climate adaptation policy integration; climate resilience promotion; South European context; regional spatial planning; sub-regional spatial planning

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1. Introduction

Climate change implies effects on anthropized and non-anthropized areas [1–4]. As for the first type of areas, the positive effects of climate change regard the increase in crop yield in some high-latitude zones and the possibility of having more than one harvest per year [5,6]. On the other hand, negative effects include more frequent extreme weather events, which are responsible for the loss of human lives, flooding, droughts, desertification, reductions in crop yield and crop losses, loss of biodiversity, and destruction of settlements and transportation and mobility infrastructures [5,7,8]. Mitigation and adaptation are interlinked strategies to respectively address the roots and the consequences of a changing climate [9]. The 'mitigation' approach addresses the causes of climate change and aims at defining actions to reduce greenhouse gas emissions. The proactive concept of 'adaptation' deals with how humans can adapt to—and benefit from—a changing climate, avoiding maladaptation phenomena [10–12]. Adaptation and resilience can be considered complementary concepts. For the sake of clarity, in this manuscript, we refer to adaptation and resilience as defined by the Intergovernmental Panel on Climate Change (IPCC), i.e., the "process of adjustment to the actual or expected climate and its effects" [13] (adaptation), and the "capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation" [13] (resilience).

Over the past few decades, international and European bodies have proposed both mitigation and adaptation strategies, such as the United Nations Framework Convention on Climate Change, the Paris Agreement (mitigation; [14]), and the European Union Strategy on Adaptation to Climate Change [15]. As for climate change adaptation (CCA), in 2013, the European Commission adopted the European Union Strategy on Adaptation to Climate Change to make member states more resilient to climate change effects. In 2021, the EU Strategy was updated and replaced [16]. According to the EU Strategy, adaptation measures must be implemented at all levels of governance especially in the Mediterranean basin, an area considered significantly affected by vulnerability to climate changes [15]. Coordination between levels of public administration and coherence between planning and management levels to respond to climate change should be improved through the adoption of national adaptation strategies [15]. Consistently, in 2015, the Italian Ministry of the Environment and Protection of Land and Sea—nowadays the Italian Ministry of the Environment and Energy Security—adopted the National Climate Change Adaptation Strategy (NCCAS) [17]. Italy is also currently in the process of adopting a National Climate Change Adaptation Plan (NCCAP, latest version: December 2022) [18]. In 2019, the Autonomous Region of Sardinia adopted the Regional Climate Change Adaptation Strategy (RCCAS), with the purpose of increasing regional climate resilience [19]. The new RCCAS has currently been updated (October 2023) but it is not in force yet.

In Sardinia, regional and sub-regional plans must be consistent with the framework defined by RCCAS. In this regard, spatial planning can play a crucial role in encouraging CCA [10,20–23] and "subnational level spatial planning tools are key to mainstreaming [CCA]" [10].

The implementation of spatial planning processes incorporates a variety of entities ranging from local to international scale, in coherence with frameworks that rely upon custom and planning tradition [24]. Three tiers of government are typically involved in spatial planning in EU member states [24]. Officially, state, region, province, and municipality are the four administrative levels instituted in Italy [25]. However, the state rarely releases national sector plans, according to a well-advanced process of decentralization of planning responsibilities to lower-level administrative bodies. Regions and sub-regional bodies adopt a range of tools to plan and manage their development, serving three purposes: actuation, operative regulation (such as land-use zoning), and coordination.

According to [26], the introduction of CCA concepts at regional and sub-regional scales can be promoted by linking adaptation and spatial planning, for example, "for flood protection and biodiversity protection" [26]. Carter et al. [27] quoted by Busayo et al. [28] stated similar concepts. In terms of adaptation, Bruneniece and Klavins [20] stressed the key role played by local and regional governments. These organizations typically have up-to-date knowledge of the local settings and factors that may facilitate or impede environmental change.

Although CCA and spatial planning are relevant to promoting climate resilience [10–12,29,30], Italy shows a certain lack of studies that specifically focus on the coherence between national CCA objectives and regional (and sub-regional) plans. We aim to investigate such a research gap and answer two research questions (RQ_s): (i) can we propose a methodological approach that allows us to assess the coherence of sectoral plans with the objectives set by the NCCAP (RQ_1)? (ii) Can we apply in practice such a methodology for a European regional planning context (RQ_2)? With RQ_1, we investigate if the logical framework approach (LFA) [31,32] is useful to assess if—and to what extent—regional and sub-regional plans adopted in Sardinia are consistent with the national CCA framework set by NCCAP. With RQ_2, the purpose is ascertaining if the methodology works in practice, i.e., if it allows one to provide public bodies with tangible results that can be considered to highlight the strengths and weaknesses of the plans, which might be the starting point for suggesting update processes.

Therefore, in this work, we aim to assess some regional and sub-regional plans for ascertaining their coherence with the missions of the NCCAP. We apply LFA to scrutinize

the plans by reconstructing their strategic framework (including objectives and actions) and assessing the plans with respect to the CCA objectives established by NCCAP.

The manuscript unfolds as follows. In the second section, we introduce and describe the method based on the Logical Framework Approach (LFA). We adopt LFA to assess the performance of the sectoral plans compared to the objectives of NCCAP. In the third and fourth sections, we respectively show and discuss the findings. In the fifth section, we answer the RQ_s and summarize the main concluding remarks.

2. Materials and Methods

Methods often adopted for the assessment of CCA mainstreaming in spatial, urban, and regional plans are based on two clusters of tools [33]. The first cluster encompasses qualitative surveys, which consist of questionnaires and semi-structured interviews that are submitted to planners, officials, and decision-makers responsible for approving or evaluating plans [34–36]. According to this approach, Measham et al. [34] focused on constraints to CCA at the local scale, i.e., the municipal level, which plays a critical role in climate adaptation. The authors focused on three municipalities in Sydney, New South Wales, Australia. The research represented the third phase of a broader project and "involved case studies focusing on key adaptation barriers identified through the workshops [. . .] These barriers related to (a) infrastructure, (b) community attitudes, and (c) planning processes" [34]. Similarly, Rauken et al. [35] stressed the need to promote CCA mainstreaming locally. The authors assessed how five Norwegian municipalities introduced CCA into existing policy sectors. To do so, "in-depth interviews with politicians and administrative staff were conducted" [35]. Finally, Cuevas [36] applied a mixed methodology to investigate CCA mainstreaming into local land-use planning in Albay, Philippines. The four-stage methodology included "survey, in-depth interviews, consultation with key informants, and document reviews" [36].

The second cluster entails qualitative–quantitative analytical evaluations of plans, according to tailored criteria and the assignment of scores, or through frequency analysis [10,11,37–39]. According to this approach, Tang et al. [37] scrutinized fifty-three local comprehensive land-use plans adopted in California to assess how the plans addressed climate change mitigation and adaptation issues. Tang et al. [37] applied a set of twenty-five indicators, with scores ranging from 0 (issue not addressed in the plan) to 2 (issue fully addressed). Similarly, Baynham and Stevens [38] examined thirty-nine official community plans adopted in the province of British Columbia, Canada, to investigate to what extent these plans integrate climate change mitigation and adaptation considerations. Woodruff [39] investigated how the CCA plan adopted by the City of Chester, southeast Pennsylvania (USA), was coordinated with nineteen planning tools prepared by different planning authorities. Woodruff [39]used a "content analysis and information system of plan methodologies" [39]. Such methods allowed Woodruff [39] to assess the level of mainstreaming, i.e., to what extent the plans integrated CCA. Ledda et al. [10] scrutinized six regional plans adopted by the Autonomous Region of Sardinia (Italy) by using a set of three criteria to assess the integration of CCA within the plans. The authors assessed if the plans integrated a clear reference to CCA strategies and explicit or implicit adaptation measures, and identified the responsible bodies for implementing CCA measures. Ledda et al. [11] assessed the mainstreaming of CCA in Sardinian regional plans and programs by using a set of four criteria, i.e., if the regional tools referred to CCA strategies, included climate analysis, contained CCA measures, and defined indicators apt for monitoring the effects of climate change and CCA measures.

Our methodological approach is closer to the second cluster of tools described above: we adopt the Logical Framework Approach (LFA) [31,32,40–44] to evaluate the coherence between objectives and actions set by sectoral plans and objectives set by NCCAP.

2.1. The Logical Framework Approach

The first version of the LFA, which was adopted in the development sector, dates back to the 1960s [40,41]. Crawford and Bryce [41] focused on the gap in project management literature concerning aid project management and pointed out the limitation of the traditional LFA—the so-called LogFrame—in the context of project monitoring and evaluation information systems. The authors pointed out four critical issues of the LogFrame, including the lack of a time dimension and its static nature. Thus, the authors proposed a modified—three-dimensional (3D)—version of the LogFrame, with the purpose of facilitating "ongoing management functions [...] beyond the design phase" [41]. Such a 3D-LogFrame emphasizes, for example, the planner's view and the project manager's view of the project, and the time dimension. Lamhauge et al. argue that "LFA has been criticized for its top-down approach imposed by large development agencies on smaller implementing partners" [42]. Despite its limitations, Lamhauge et al. [42] found that six development agencies adopted LFA and the related LogFrames "to monitor and evaluate their adaptation [to climate change] related and specific activities" [42]. Golini et al. [43] remarked that the logical framework is widely adopted by non-governmental organizations to implement social impact assessment and project execution concerning international aid projects. One of the most recent forms of LFA is based on the use of a matrix—a LogFrame Matrix—such as the one shown in Table 1.

Table 1. The LogFrame Matrix as in Schmidt [43].

	Objectives	Success Measures	Verification	Assumptions
↻	**Goal**	...	...	...
↻	**Purpose**	...	...	...
↻	**Outcomes**	...	...	...
	Inputs	...	...	...

According to Schmidt [44], the project design lies in the answers to four questions: what are we trying to accomplish and why (that refers to the objectives)? How will we measure success (measures and verifications)? What other conditions must exist (assumptions)? How do we get there (inputs)?

Zoppi [31] proposed a spatial planning approach that can be applied to the definition of conservation measures for EU Natura 2000 sites (N2Ss). The "methodology is based on a process which entails a continuous and intertwining planning and assessment activity founded on a logical framework (LF), which identifies conceptual connections between sustainability objectives related to the spatial contexts at stake and the operational planning actions concerning the integration of conservation measures related to N2Ss into the [Regulation of the Marine protected areas]" [31]. The author implemented the methodological approach in a protected marine area located in North-Eastern Sardinia, Italy.

Leccis [32] focused on the integration—into local plans—of the objectives set by the Regional Strategy for Sustainable Development adopted in Sardinia (Italy) in 2021. To do so, she proposed a methodology inspired by LFA, which consisted of four phases: "the definition of the sustainability-oriented objectives, the assessment of policy consistency, the definition of the specific objectives and the definition of the actions" [32].

In this study, we follow Zoppi [31] and Leccis [32] and design a method consisting of three stages: (i) the selection of adaptation objectives and actions set by NCCAP and relevant to spatial planning, (ii) the selection of spatial plans adopted at the regional or metropolitan level, and (iii) application of LFA to assess the level of integration of CCA concepts into the plans.

The first phase is aimed at identifying CCA objectives and actions of interest to land use and urban planning. The full set of 18 sectors covered by the NCCAP (including aquaculture, agriculture, desertification, and other sectors) was considered as being of potential interest to urban and spatial plans. The 18 sectors branch out into 137 adaptation objectives, which are linked to 360 adaptation actions/measures. Both objectives and actions have been preliminarily examined to assess the potential relevance to land use governance. After this filtering, we obtained 74 objectives (see Appendix A) and 251 actions, which can be included in regional and sub-regional plans.

In the second phase, we selected four plans and assessed their performance, in terms of CCA integration. The analysis focused on plans approved in recent years, after January 2015, when the Autonomous Region of Sardinia officially promoted the process of adopting a regional adaptation strategy for CCA [19]. Thus, we selected the Regional Cycle Mobility Plan (RCMP), the Strategic Plan of the Metropolitan City of Cagliari (SPMCC), the Flood Risk Management Plan (FRMP), and the Regional Environmental Energy Plan (REEP).

In the third phase, we scrutinized the plans by adopting LFA, according to Table 2.

Table 2. The Logical Framework Approach (LFA) adopted in this research.

(a) Adaptation Objectives Set by NCCAP	(b) Objectives Set by the Sectoral Plan	(c) Assessment of Coherence between Plan Objectives and Adaptation Objectives Set by NCCAP	(d) If Necessary, Redefinition of Objectives of the Sectoral Plan to Introduce CCA Considerations	(e) Measures Included in the Sectoral Plans, Which Are Consistent with the Adaptation Objectives Set by NCCAP	(f) Assessment of Coherence between Measures Included in the Plans and the Adaptation Objectives Set by NCCAP
...	...	...	...	...	...

The LFA has been applied as follows. First, the objectives defined by the sectoral plan (Table 2, column b) have been compared to the 74 objectives selected from the NCCAP (Table 2, column a). Second, column (c) has been populated with the objectives of the NCCAP that were consistent with the objectives of the sectoral plan. In the case of non-consistency, the correspondent rows have been excluded from the assessment. Third, for each objective of the sectoral plan, we assessed the level of integration of the consistent NCCAP objectives. Column (d) has been populated as follows: the objective of the sectoral plan has been kept unchanged when it has been assessed as coherent with the NCCAP objectives; it has been reframed and improved when partial integration occurred. Fourth, we compared the objectives of the NCCAP relevant to the objectives of the sectoral plan with the measures included in the sectoral plan (Table 2, column e), which are linked to the objectives of the sectoral plan. In this step, column (f) has been populated making explicit how each action contributes to achieving the objective set by the NCCAP. The integration of CCA in the measures could be improved by suggesting plausible corrections. Non-relevant measures have been excluded from the assessment.

Finally, for each sectoral plan, an ad hoc table summarized the extent to which the objectives and measures of the sectoral plan integrated the adaptation objectives of the NCCAP. In addition, we proposed a global score (i.e., a score that is calculated with respect to the full set of objectives and measures defined by the sectoral plan) and a local score (i.e., a score that is calculated with respect to the objectives and measures defined by the sectoral plan and included in LFA; see Table 3).

Table 3. The LF matrix for the assessment of the coherence of the objectives (O)/actions (A) set by the sectoral plans with respect to the objectives set by NCAAP.

A	B	C	D	E	F	G	H	I	J	K
							Global Score		**Local Score**	
Sectoral plan	Objectives (O)/Actions (A)	Not relevant O/A	Not relevant O/A in %	O/A included in LF matrix	Fully consistent O/A	Partially consistent O/A	Fully consistent O/A in %	Partially consistent O/A in %	Fully consistent O/A in %	Partially consistent O/A in %
…	…	…	…	…	…	…	…	…	…	…

As for the objectives, the quantitative assessment reported in Table 3 involves the following steps: (i) counting the number of objectives defined by the sectoral plan deemed consistent and/or integrable in terms of CCA; (ii) assessment of the objectives that are consistent with (or integrable in terms of) CCA. The assessment considered two classes: fully satisfactory integration (no changes in the objective of the plan are required) and partial integration (the objective of the plan needs to be integrated in terms of CCA considerations); (iii) quantification and percentage of objectives with fully satisfactory and partial CCA integration. Similarly, for the measures, the quantitative assessment involves the following steps: (i) counting the number of measures defined by the sectoral plan deemed consistent and/or integrable in terms of CCA; (ii) assessment of the measures that are consistent with (or integrable in terms of) CCA. The assessment considered two classes: (i) fully satisfactory integration (no changes in the measures are required) and (ii) partial integration (the measures need to be integrated in terms of CCA considerations); (iii) quantification and percentage of measures with fully satisfactory and partial CCA integration. For both objectives and measures, the local scores refer to the percentage with respect to objectives/measures deemed relevant to CCA objectives of the NCCAP, while the global scores refer to the full set of objectives/measures defined by the sectoral plan. As an example, considering Table 3, the global score (GS) in column D (GS_D) is calculated as in Equation (1) (in percentage):

$$GS_D = C/B \times 100\%. \quad (1)$$

While the local score (LS) in column J (LS_J) as in Equation (2) (in percentage):

$$LS_J = H/E \times 100\%. \quad (2)$$

2.2. The Plans Considered in This Study

We considered plans adopted in Sardinia (Italy; Figure 1). Table 4 illustrates the plans assessed in this study: Regional cycling plan (RCP), Strategic plan of the metropolitan city of Cagliari (SPMCC), Flood risk management plan (FRMP), and Regional environmental energy plan (REEP).

Figure 1. Geographical context. In red is the island of Sardinia (Italy).

Table 4. Sectoral plans considered in this study.

Plan	Acronym	Year	Description	References
Regional cycling plan	RCP	2018	The design of the regional cycling mobility system includes bicycle routes connecting the places of arrival (ports and airports) to the main settlements, natural assets, and cultural and historical landscapes. The overall rationale is encouraging sustainable and seasonal tourism.	Autonomous Region of Sardinia [45]
Strategic plan of the metropolitan city of Cagliari	SPMCC	2021	This plan is an intermediate coordination tool including spatial planning and programming measures concerning seventeen municipalities. The plan defines guidelines and development goals for the medium and long term.	Metropolitan City of Cagliari [46]
Flood risk management plan	FRMP	2021	The plan aims at increasing territorial resilience to flooding over Sardinia. Its general principles are: reducing floods by acting on the frequency of occurrence, reducing vulnerability by acting on the elements at risk, and increasing risk awareness by developing actions that increase knowledge, culture, and information about flood risk.	Autonomous Region of Sardinia [47]
Regional environmental energy plan	REEP	2016	The plan aims to address the regional energy system by matching energy demand and supply and choosing renewable and not renewable energy sources, according to international, European, national, and regional plans and documents.	Autonomous Region of Sardinia [48]

While RCP, FRMP, and REEP are regional plans, SPMCC is a sub-regional plan that has been considered under the specific request of the regional administration. Table A1 in Appendix A summarizes the full set of objectives and part of the measures defined by the sectoral plans, which are totally or partially consistent with the national adaptation plan. We do not report the full set of measures, for the sake of conciseness.

3. Results

In this section, we summarize the results of the application of LFA to the assessment of the coherence of the sectoral plans to the NCCAP [18], by objectives (Table 5) and actions/measures (Table 6).

Table 5. Coherence analysis by objectives: results. Global and local score (GS and LS).

A	B	C	D	E	F	G	H	I	J	K
							Global Score		**Local Score**	
Sectoral plan	Objectives	Not relevant objectives	Not relevant objectives, GS	Objectives included in LF	Fully consistent objectives	Partially consistent objectives	Fully consistent objectives	Partially consistent objectives	Fully consistent objectives	Partially consistent objectives
RCP	12	0	0%	12	5	7	42%	58%	42%	58%
SPMCC	11	2	18%	9	6	3	55%	27%	67%	33%
FRMP	11	2	18%	9	2	7	18%	64%	22%	78%
REEP	17	6	35%	11	6	5	35%	29%	55%	45%

Table 6. Coherence analysis by actions/measures: results. Global and local score (GS and LS).

A	B	C	D	E	F	G	H	I	J	K
							Global Score		**Local Score**	
Sectoral plan	Actions	Not relevant actions	Not relevant actions, GS	Actions included in LF	Fully consistent actions	Partially consistent actions	Fully consistent actions	Partially consistent actions	Fully consistent actions	Partially consistent actions
RCP	52	15	29%	37	34	3	65%	6%	92%	8%
SPMCC	30	6	20%	24	14	10	47%	33%	58%	42%
FRMP	49	0	0%	49	46	3	94%	6%	94%	6%
REEP	68	29	43%	39	34	5	50%	<1%	87%	13%

Table A1 in Appendix A includes the objectives of the sectoral plans that are consistent with the objectives set by the NCCAP. Objectives of the sectoral plan not fully consistent with the objectives of NCCAP have been reframed in a more coherent description. Actions/measures connected to the objectives are too many to be included in this paper; we report on some examples.

In the remainder of this section, we comment on the results of each sectoral plan.

3.1. Regional Cycling Plan (RCP)

The full set of twelve objectives is consistent with the objectives of NCCAP: five have been found to be fully consistent (GS 42%, LS 42%), while seven need to be integrated in terms of CCA (GS 58%, LS 58%). Fully consistent objectives include 'Identification of a network of major regional bicycle routes to be implemented with a specific typology, priority and hierarchy, through modification of the characteristics and/or functions of the existing road network and/or construction of independent bicycle paths' and 'Design and implement facilities and tools for the involvement of interested users (i.e., practitioners), through marketing, communication, information, education, and knowledge actions'. The construction of bicycle routes/paths is relevant to CCA as RCP emphasizes details such as limiting the use of asphalt, using materials that facilitate water drainage, ensuring good shading of cycling routes (useful in the hottest season), and planning cycle tourism activities to avoid the hottest season in order to meet the need to implement CCA strategies that safeguard the health of cyclists. An example of a partially consistent objective is 'Recover and modernize the heritage of decommissioned railway tracks, redeveloping them into "greenways" and connecting them to Sardinia's bicycle tourism network', which has been reformulated as 'Recover and modernize the heritage of decommissioned railway tracks, redeveloping them into "greenways" and connecting them to Sardinia's bicycle tourism network, making use of technologies and materials resilient to high temperatures and the increase in extreme climate events'.

RCP includes fifty-two actions. Thirty-seven out of fifty-two actions have been found to be relevant to climate adaptation: thirty-four are fully consistent with the objectives of NCCAP (GS 65%, LS 92%), while three are partially consistent (GS 6%, LS 8%). As an example, actions fully consistent included 'In the preliminary design phase, it is necessary to ask for verification of the possible interference of the works with the hydraulic or geological-geotechnical hazard areas identified by the sector plans in force (Hydrogeological Structure Plan, Fluvial Zone Plan, Flood Risk Management Plan)', which is associated with the objective 'Promote the implementation of bicycle routes considering naturalistic, scenic and historical-cultural features as well as hydrogeological risk and climate change'. The actions not fully coherent with the objectives of the NCCAP included, for example, 'Design and implementation of specialized information signs'.

3.2. Strategic Plan of the Metropolitan City of Cagliari (SPMCC)

SPMCC shows a very good level of consistency with the objectives of the NCCAP. Nine out of eleven objectives have been selected as consistent with the objectives of the NCCAP: six objectives have been found to be fully consistent (GS 55%, LS 67%), while three need to be integrated in terms of CCA (GS 27%, LS 33%). Some objectives of SPMCC have been reformulated in terms of CCA. As an example, the objective 'Improve interaction with local stakeholders' has been reformulated to 'Improve interaction with local stakeholders (for example, to promote aspects related to ecosystem services and climate change adaptation; raise public awareness, etc.)', 'Qualitatively improve the urban and peri-urban fabric' to 'Qualitative improvement and securing of urban and peri-urban fabric', and 'Support innovation and quality in the production of raw materials' to 'Support innovation and quality in the production of raw materials, with emphasis on sustainability'. The remaining objectives have not been reformulated.

The full set of actions is associated with multiple specific objectives of SPMCC. For example, 'Increasing administrative transparency and accessibility' and 'Reinforcing participation' are associated with 'Improve interaction with local stakeholders'; 'Reinforcing inter-municipal and inter-sectoral coordination' and 'Reinforcement of management and organizational structures internal to metropolitan institutions' with 'Strengthen Capacity Building processes'. Twenty-four out of thirty actions have been included in the LF matrix. Of these actions, fourteen have been identified as fully coherent with all the objectives of NCCAP (GS 47%, LS 58%) and ten partially coherent (GS 33%, LS 42%). An action with satisfactory CCA integration is, for example, 'Increasing administrative transparency and

accessibility' pertaining to five objectives of the NCCAP linked to the specific objective 'Improve interaction with local stakeholders'. Ensuring easy access to documents (manuals, reports, guidelines, etc.) promoting CCA should improve interactions with local communities, who can figure out why and how CCA is relevant to potentially contribute to saving human lives and making buildings and transport and mobility infrastructures more climate resilient. The actions that were not fully coherent with the objectives of NCCAP included, for example, 'Development of large transport and mobility infrastructures'. In fact, this action is not consistent with the full set of objectives set by the national plan that are related to the objective 'Improvement of internal and external mobility'.

3.3. Flood Risk Management Plan (FRMP)

FRMP shows a good level of consistency with the objectives of the NCCAP. Nine out of eleven objectives have been assessed as consistent with the objectives of the NCCAP: two have been found to be fully consistent (GS 18%, LS 22%), while seven need to be integrated (GS 64%, LS 78%). The objectives that are strongly pertinent to the objectives of the NCCAP are 'Mitigation of damage to infrastructures that serve and maintain economic activities (power plants and networks, water treatment plants, sewage treatment plants, etc.)' and 'Mitigation of damage to real estate'. The less relevant objective is 'Mitigation of permanent or long-term adverse effects on the ecological status of water bodies according to the WFD, with regard to the achievement of the environmental objectives of Directive 2000/60/EC'.

The forty-nine measures were not directly linked to the specific objectives. Therefore, a preliminary analysis was carried out to match the specific objectives with the relevant actions to apply the LFA. Of these actions, forty-six have been identified as fully coherent with all the objectives of the NCCAP (GS 94%, LS 94%), and three are partially coherent with some objectives of the NCCAP (GS 6%, LS 6%). Fully coherent actions include, for example, 'Guidelines for the implementation of interventions with naturalistic engineering techniques' and 'Measures for the improvement of territorial governance and land use regulations aimed at reducing hydro geomorphological hazard and risk'.

3.4. Regional Environmental Energy Plan (REEP)

REEP shows an improvable level of consistency with the objectives of the NCCAP. Eleven out of seventeen objectives have been found to be consistent with the objectives of the NCCAP. Each of the eleven objectives has been compared with each objective of the NCCAP. Six objectives were clearly related to spatial and urban planning and showed strong relevance to the objectives of the NCCAP (GS 35%, LS 55%), while five are partially consistent (GS 29%, LS 45%). The fully coherent objectives included 'Develop and integrate energy storage technologies' (which can prevent power outages due to excessive use of air conditioning, especially in the hottest season), 'Increasing the flexibility of the electric power system', and 'Promote energy production for self-consumption through renewable sources' (production of electricity from various sources, to ensure blackout-free supply), 'Strengthen the "governance" of the regional energy system' (define adequate strategies to address the high demand for energy due extreme hot or cold), and 'Energy monitoring' (to design proper countermeasures against blackout). Some objectives of REEP have been reformulated in terms of CCA: as an example, 'Methanize the Region of Sardinia through Liquefied Natural Gas' has been reformulated into 'Methanize the Region of Sardinia through Liquefied Natural Gas as alternative energy source' and 'Manage the energy transition of fossil sources (Oil and Coal)' into 'Manage the energy transition of fossil sources (Oil and Coal) towards the use of alternative energy sources'.

As regards the link 'specific actions-objectives', part of the actions are associated with a single objective. For example, the action 'Definition of Governance for the implementation and monitoring of the Sardinian Energy and Environmental Plan' is associated with the objective 'Energy Monitoring'. On the other hand, some actions are linked to more than one specific objective of REEP: for example, the actions 'Integration of electric mobility and storage availability for the management of the electricity system at the distributed level' and 'Development of a management system of the region's water storage system potential for utilizing the potential of reservoirs for energy storage purposes thereby preserving their primary purposes' are linked to the plan objective 'Develop and integrate energy storage technologies'. REEP included sixty-eight actions: the LF matrix contains thirty-nine of them linked, by groups, to the eleven specific objectives. Thirty-four out of thirty-nine actions are fully satisfactory as regards the integration of CCA considerations (GS 50%, LS 87%), while five actions show improvable integration (GS < 1%, LS 13%). The actions fully consistent with the objectives of the NCCAP included 'Development of a management system for the potential of the region's water storage system for the use of the potential of water basins for energy storage purposes, thus preserving their primary purposes' and 'Concertation at European and national level of Capacity Payment instruments for increasing the flexibility of the electricity system of the Region of Sardinia'. The actions not fully coherent with the objectives of the NCCAP included, for example, 'Communication Plan of the Regional Energy Strategy and the Energy and Environmental Plan of the Region of Sardinia during all its phases' and 'The Region of Sardinia considers it strategic to promote the development of skills and technologies for the use of low-emission coal', are correlated with some objectives of the NCCAP (not necessarily the same objectives).

4. Discussion

LFA allowed us to assess if—and to what extent—the objectives and actions set in the scrutinized sectoral plans were consistent with the objectives defined by the NCCAP. The application of LFA highlighted a variable consistency of the plans with respect to the NCCAP in terms of CCA integration. RCP shows remarkable coherence with the NCCAP. All the objectives set by the plan are consistent with the NCCAP. This is likely due to the recent adoption of the plan (2018). In fact, the planning process was developed when the NCCAS was already in force [17], the draft of the NCCAP was available, and the Autonomous Region of Sardinia was working on the Regional Strategy for Adaptation to Climate Changes (RSACC). SPMCC, FRMP, and REEP show partial but good coherence with the objectives of the NCCAP. SPMCC, FRMP, and RCP are quite recent plans, while REEP dates back to 2016. However, REEP unexpectedly shows eleven out of seventeen objectives pertinent to the objectives of NCCAP: therefore, we think this could be considered a satisfactory result as in 2016, CCA was in its infancy in Sardinia (and in Italy as well). Finally, FRMP—which is arguably one of the most important plans for CCA—shows only two out of nine objectives that are fully consistent with the NCCAP. In this regard, an update of the plan would be desirable to make its objectives fully consistent with the national CCA framework. On the other hand, the full set of actions included in FRMP have been considered in LFA and most of them are fully consistent with the NCCAP.

LFA has stressed both the strengths and weaknesses of the sectoral plans. This is relevant to spatial planning as the lack of CCA consideration in the planning process could lead to approved documents that have scarce relevance to address climate change. At worst, the plans may include measures/actions that have negative effects on people and environment (maladaptation) [12]. Thus, LFA appears to be a useful solution to integrate climate resilience concepts—as well as sustainability concepts [31]—into planning tools. The strategic environmental assessment (SEA) has the potential to address the inclusion of both climate resilience and sustainability issues into strategic tools, e.g., policies and plans [11,49]. According to the best practices, SEA should be applied in the early stages of the planning process and allow the public to provide a significant contribution to the plan

during the so-called 'public consultation process' [10,50]. Then, we suggest LFA may also be part of SEA to integrate CCA in plans that affect the environment and people's lifestyles.

The LFA-based method adopted in this study can be replicated in other similar geographical and institutional contexts and other planning sectors as in Zoppi [31] and Leccis [32]. This could be relevant to the promotion of CCA across different types of plans and programs. In fact, these tools regulate human activities and land use at different scales, from regional [51] to local [52]. Adequate integration of CCA objectives and actions set at European and national levels into sectoral plans should be one of the first steps for defining operational measures, i.e., tangible measures for increasing the climate resilience of people, landscapes, and infrastructures, such as green infrastructures, adaptive land use management, early warning systems, and building insulation [30]. Tangible measures must be context-specific, i.e., the measures need to be tailored to specific contexts to be effective [10,53].

The successful achievement of desired objectives depends on the coherence between policies [54]. In this regard, LFA has contributed to linking national CCA objectives with regional and sub-regional plans that affect land use in Sardinia and this is relevant to CCA governance as "the consideration of European or national [CCA] principles in the [strategies, plans, programs, and projects] should be interpreted as the willingness of policy makers to promote vertical coherence towards climate-resilient cities in operational terms" [30]. The method adopted in this research has been used for drafting the new Sardinian regional strategy for CCA [33].

5. Conclusions

In this manuscript, we aimed to answer two research questions (RQ_s): (i) can we propose a methodological approach that allows us to assess the coherence of sectoral plans with the objectives set by the national climate change adaptation plan (NCCAP; RQ_1)? (ii) Can we apply in practice such a methodology for a European regional planning context (RQ_2)?

As for RQ_1, the logical framework approach (LFA) proved to be useful to assess if—and to what extent—regional and sub-regional plans adopted in Sardinia were consistent with the national climate change adaptation (CCA) framework set by the NCCAP. The method based on an application of LFA allowed us to point out the relevance and coherence between the objectives set by NCCAP and the objectives and actions defined in sectoral plans.

As for RQ_2, the purpose was ascertaining if the methodology worked in practice, i.e., if it allowed one to provide the regional administration with tangible results that can be considered to highlight strengths and weaknesses in the plans, which may be the starting point for suggesting updates of both the plans and current regional strategy for CCA. The application of LFA on four plans considered in this study allowed us to identify objectives and actions that integrate the goals of the NCCAP in a satisfactory way. Objectives not fully consistent with the national plan can be integrated with CCA contents. This is relevant to promoting climate resilience issues in plans that have clear effects in terms of spatial, landscape, and urban planning.

The method shows strengths and weaknesses. As regards the strengths, the method may be replicable in similar institutional and geographical contexts as it is rooted in a scientific basis and similar approaches have already been applied somewhere else. LFA provides a simplified overview of the findings obtained in the plan assessment process, which is described step by step by the assessor. Thus, the assessment is transparent, i.e., policy-makers, decision-makers, the public, and interested bodies can go through the entire plan evaluation process. Ensuring participation and transparency in the planning process is key to achieving consensus-based final decisions. As regards the limitations, the LFA matrices show the results clearly, but as in any evaluation process, the findings are affected by the evaluator's subjectivity. Finally, plans with several objectives and/or actions imply the use of huge LF matrices that are difficult to manage. As an example, the LF matrix of

FRMP consisted of more than 26,000 words in almost 7200 records. Then, the management of similar matrices may be challenging.

From 2020 to 2023, we were involved in the updating of the Regional Climate Change Adaptation Strategy (RCCAS) adopted by the Autonomous Region of Sardinia in 2019. We had a twofold objective: on the one hand, we aimed to assess if the principles and contents of the former RCCAS (2019) were already partially or fully integrated within spatial planning tools (mainstreaming), i.e., the sectoral plans; on the other hand, based on the results obtained, we aimed at understanding how we could update/improve the RCCAS. In this regard, the NCCAP was used as a reference framework to integrate the new RCCAS in terms of CCA contents. Both the methodological approach and findings of this research are part of the new RCCAS, which is currently under approval by the Autonomous Region of Sardinia. As future research, we aim to investigate if the new regional strategy will be integrated into regional and sub-regional planning practice.

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Appendix A

Objectives of NCCAP considered relevant to spatial and urban planning:

1. improve thermal comfort and quality of living in peri-urban areas, suburbs, historic centers, and public spaces;
2. improve water supply system efficiency in peri-urban areas, suburbs, historic centers, and public spaces;
3. increase soil permeability and hydraulic system efficiency in peri-urban areas, suburbs, historic centers, and public spaces;
4. promote planning and design for risk prevention and facilitating monitoring;
5. increasing knowledge, education and training on vulnerability and adaptation at the urban scale;
6. counteract the degradation of materials and structures;
7. assess irreversible loss of cultural artifacts and the natural landscape;
8. transfer knowledge and preserve traditional building construction and landscape management techniques and practices;
9. experiment with materials, structures, facilities, and technologies that are more resilient to increasing temperatures and rainfall variability;

10. integrate climate change risks into planning and design toward resilience and adaptation;
11. securing land with respect to hydrogeological risk;
12. improve the effectiveness of monitoring, warning and emergency response systems to transport services;
13. raise awareness, train and engage key players in the transport sector on climate change adaptation;
14. adapt tourism offerings to changing climate conditions and the unavailability of traditional tourist attractions;
15. reduce impacts through green infrastructure
16. improvement of risk management for tourism operators;
17. preventing health risks to tourists due to extreme events or other negative situations that may jeopardize the tourist destination;
18. increase the use of alternative energy sources;
19. increase the resilience of the energy system;
20. promote and increase better management of heating and cooling energy demand;
21. reduce energy losses from transmission and distribution networks;
22. adapt ecological corridors and protected areas to changing species ranges;
23. countering biodiversity loss and alien species invasion and adapting ecological corridors and protected areas to changing species ranges;
24. improve the integration of adaptation into biodiversity planning, management and conservation;
25. encourage research, knowledge and monitoring of the impacts of climate change and adaptation on flora and fauna and ecosystem services;
26. promote education, outreach and awareness, and deepen socio-economic aspects related to ecosystem services;
27. conservation and protection of natural marine environments to maintain high levels of functionality and production of ecosystem goods and services;
28. counteract the loss of biodiversity and invasion of alien species;
29. promotion of sustainable management practices of marine ecosystems;
30. reduction of direct anthropogenic impacts in marine ecosystems;
31. ensure the functionality of river ecosystems even in lean periods, environmental sustainability concerning the use of water resources, and socio-economic sustainability of related activities;
32. Monitor the supply of nutrients and suspended solids in transitional environments to plan actions upstream or downstream of the watercourses that flow into the transitional systems;
33. regulate water concessions and uses from an ecosystem management perspective;
34. restore optimal conditions of transitional environments and recreating refuge and trophy conditions for benthic macrofauna and fish [. . .];
35. implementation of agricultural practices beneficial to climate and environment;
36. promote and support research for risk assessment and development of adaptation and mitigation solutions;
37. improve education and training for resource management in the agricultural sector;
38. increase resilience in forestry and maintenance of ecosystem services by promoting sustainable forest planning and management, supporting ecosystem service-based solutions;
39. promote the sustainable and efficient use of forest resources by upgrading and improving facilities and infrastructure;
40. promote forest planning, including from the perspective of risk prevention and management;
41. protect and preserve biodiversity and increase forestry resilience [. . .];
42. promote and strengthen actions related to education and training;
43. increase resilience through planning of aquaculture sites and facilities and farming systems;

44. improve water resource management for inland aquaculture;
45. improve environmental sustainability of production activities [. . .];
46. reduce the vulnerability of aquaculture productions, market and trade;
47. development of a network for monitoring the impacts and adaptation to climate change of the aquaculture sector;
48. prevent and mitigate the effects of extreme events with non-invasive interventions [. . .];
49. encourage and support ecosystem service-based solutions aimed at preventing and mitigating the effects of extreme events attributable to climate changes;
50. develop public-private governance tools for increasing resilience;
51. increase awareness and knowledge of the risks and vulnerabilities of hazardous activities and infrastructure exposed to NaTech events attributable to climate change and promoting training of practitioners;
52. help to reshape and reduce fishing activity, with possible declines in mortality for stocks;
53. increase or change the speed and volume of water runoff;
54. improve the effectiveness of resource use regulation and planning, including by improving the effectiveness of monitoring to prevent water crises;
55. improve the efficiency of water infrastructure;
56. improve efficiency in the use of the resource;
57. increase communities awareness;
58. ensure the preservation and protection of ecosystems and habitats, increase biodiversity;
59. structurally protect the coast from the action of sea rise, erosion and storm surge events;
60. reduce and manage any agricultural losses caused by flooding and storm surge events;
61. reduce and/or prevent the exposure of human assets and infrastructure to risks related to exposure to the effects of flooding and erosion by protecting shorelines;
62. reduce exposure and vulnerability of coastal communities to storm surge events;
63. reduce the risk of contamination due to sewage and urban runoff;
64. improve knowledge through the development of a system of indicators and a monitoring network of land degradation and drought impacts;
65. improve the effectiveness/efficiency of monitoring actions;
66. prevent and mitigate salinization in coastal areas;
67. raise awareness of decision makers and citizens about desertification and land degradation and the impacts of drought;
68. improve knowledge of critical geological and hydraulic issues in the territory and the risks associated with them, and land monitoring for the production of up-to-date databases;
69. improve knowledge of the state of artifacts and infrastructure to increase their resilience;
70. improve emergency management by administrations and increasing public participation;
71. improve land management and maintenance;
72. improve adaptive capacity through increased knowledge and enhanced air quality monitoring;
73. risk assessment procedures and resilience enhancement of integrated water services;
74. develop information and monitoring systems related to urban heat islands.

Table A1. The full set of objectives after filtering, which allowed us to remove plans objectives inconsistent with the national adaption plan. Objectives and measures after the application of the Logical Framework Approach: an asterisk * identifies the improved objectives; in italics the changes.

Plan	Objectives	Measures (M)
Regional cycling plan (RCP)	(RCP01*) Plan a regional, metropolitan, and urban bicycle mobility system that includes physical and social infrastructure components *also considering the risks associated with climate change among the infrastructure planning criteria*. (RCP02) Identification of a network of major regional bicycle routes to be implemented with a specific typology, priority and hierarchy, through modification of the characteristics and/or functions of the existing road network and/or construction of independent bicycle paths. (RCP03*) Establish facilities to be used as cycle services for different uses (stopping, shelter, vehicle repair, refreshment, etc.) along the routes, *also with the aim of preventing risks to the cyclist's health if extreme events linked to climate changes occur*. (RCP04*) Identify the location of intermodal nodes with public/private transport, *which allow the cyclist to choose alternative routes even in the event of emergencies linked to climate change (e.g., sudden adverse weather conditions)*. (RCP05*) Identify areas of land suitable for bicycle use, which allow the enjoyment of natural, historical landscape and cultural resources while respecting their peculiarities -*by ensuring the protection of ecosystems and habitats*- and which integrate with other sustainable mobility and local development actions. (RCP06) Design and implement facilities and tools for the involvement of interested users (i.e., practitioners), through marketing, communication, information, education, and knowledge actions. (RCP07*) Promote the implementation of bicycle routes that have homogeneous characteristics and the use of environmentally desirable technologies and products, *which offer the best performance in terms of climate resilience (increase in temperatures and variability of rainfall)*. (RCP08*) Promote the implementation of bicycle routes that pay attention to naturalistic, scenic and historical-cultural features and take into account the critical issues of the regional land in regard to hydrogeological disruption and climate change phenomena *(extreme weather events, heat islands etc.)*. (RCP09*) Recover and modernize the heritage of decommissioned railway tracks, redeveloping them into "greenways" and connecting them to Sardinia's bicycle tourism network, *making use of technologies and materials resilient to high temperatures and the increase in extreme climate events*. (RCP10) Wherever practicable, locate facilities for bicycle tourism by recovering disused buildings, redeveloping artifacts, while respecting the contexts in which they are placed. (RCP11) Encourage Local Authorities to equip themselves with planning tools for an urban, municipal, wide-area cycling mobility system (e.g., municipal and inter-municipal cycle-plans), to be included within General Urban Traffic Plans and Sustainable Mobility Plans for large urban settlements. (RCP12) Identify bicycle routes to be interconnected to European and national bicycle networks.	(RCP03*_M01) Identification and implementation of rest areas, one every 7/10 km of route. (RCP07*_M01) Introduce minimum environmental criteria in the acts of provision of resources for the implementation of individual projects. (RCP08*_M01) Where possible, plan the route of cycle paths along shaded roads and, where necessary, plan the planting of trees and shrubs to shade the routes during the hottest hours of the day. (RCP09*_M01) Redevelopment of large infrastructure (tunnels, bridges). [. . .]

Table A1. *Cont.*

Plan	Objectives	Measures (M)
Strategic plan of the metropolitan city of Cagliari (SPMCC)	(SPMCC01*) Improve interaction with local stakeholders *(for example, to: promote aspects related to ecosystem services and climate change adaptation; raise public awareness, etc.)*. (SPMCC02) Strengthen Capacity Building processes. (SPMCC03) Improve internal and external mobility. (SPMCC04) Strengthen the energy and digital infrastructure system. (SPMCC05*) Know, safeguard, improve, *and monitor* natural capital. (SPMCC06) Qualitatively improve the urban and peri-urban fabric. (SPMCC07*) Support innovation and quality in the production of raw materials, *with emphasis on sustainability*. (SPMCC08) Strengthen industry and handicrafts. (SPMCC09) Support digital transformation and service diversification.	(SPMCC01*_M01) Improve administrative transparency and accessibility. (SPMCC01*_M02) Strengthening participation. (SPMCC05*_M01) Fire risk mitigation. (SPMCC05*_M02) Reduction of coastal erosion. (SPMCC06_M01) Restoration of real estate assets (SPMCC07*_M01) Strengthen the productive activity of wetlands. (SPMCC07*_M02) Strengthen and differentiate the agricultural production supply. [. . .]

Table A1. *Cont.*

Plan	Objectives	Measures (M)
Flood risk management plan (FRMP)	(FRMP01*) Mitigate the risk to life and health, both as an immediate impact and as a secondary consequence, *improving the efficiency in the use of the resource (increasing the use of new, more resilient materials)*. (FRMP02*) *Increase the permeability of soils to reduce damages to systems that* ensure livelihoods such as power and water networks and strategic systems such as hospitals, schools, universities, nursing homes, shelters, city halls, prefectures, barracks, prisons, . . . (FRMP03*) *Increase soil permeability and* mitigate possible flood damage to the landscape system. (FRMP04*) Safeguard the heritage of cultural, historical, and architectural assets, including archaeological sites, monuments, museums, buildings *to avoid irreversible loss*. (FRMP05*) Mitigate damage to the transportation infrastructure network (roads, highways, railways, airports, etc.) *through the integration of the concepts of risk, climate adaptation, and resilience in planning and design*. (FRMP06) Mitigate damage to infrastructure that enables the maintenance of economic activities (power plants and networks, hydro-power, water treatment plants, sewage treatment plants, etc.). (FRMP07*) *Improve landscape management and maintenance by mitigating damage* to agricultural and rural activities (livestock, crops, silvicultural activities, fishing, mining). (FRMP08*) Mitigate damage to public and private economic and productive system, commercial and industrial activities, *and ensure the conservation and protection of ecosystems and habitats*. (FRMP09) Mitigate damage to real estate.	(FRMP01*_M01) Measures for the improvement of land-government and land-use regulations aimed at reducing hydro geomorphological hazard and risk. (FRMP01*_M02) Update of the Atlas concerning the areas of interference between Natura 2000 sites and areas of hydraulic hazard. (FRMP01*_M03) Update of the technical directives for the design, construction, and maintenance of new road crossing works. (FRMP02*_M01) Measures for the improvement of land-government and land-use regulations aimed at reducing hydro geomorphological hazard and risk. (FRMP02*_M02) Regulatory guidance and guidelines for the relocation of elements exposed to risk and the reduction of buildings' vulnerability. (FRMP02*_M03) Update of the technical directives for engineering works and maintenance of slopes. [. . .]

Table A1. *Cont.*

Plan	Objectives	Measures (M)
Regional environmental energy plan (REEP)	(REEP01*) *Increase knowledge, education, and training on the integration of electrical*, thermal and mobility energy systems through Information and Communication Technology enabling technologies. (REEP02) Develop and integrate energy storage technologies. (REEP03) Increasing the flexibility of the electric power system. (REEP04) Promote energy production for self-consumption through renewable sources. (REEP05*) Methanize the Region of Sardinia through Liquefied Natural Gas *as alternative energy source*. (REEP06*) Manage the energy transition of fossil sources (Oil and Coal) *towards the use of alternative energy sources.* (REEP07*) Save energy in the electric, thermal, and transport sectors *and increase the use of alternative energy sources*. (REEP08*) Promote energy research and innovation *with emphasis on renewable sources and energy saving*. (REEP09) Strengthen the "governance" of the regional energy system. (REEP10*) Promote energy awareness by ensuring active participation in the implementation of plan choices *and promoting the use of alternative sources and energy saving*. (REEP11) Energy Monitoring.	(REEP04_M01) Implementation in regional and municipal public buildings of interventions to achieve 50% self-consumption of already installed production. (REEP06*_M01) The Autonomous Region of Sardinia considers the promotion of the development of skills and technologies for the use of low-emission coal to be strategic. (REEP07*_M01) Replacement by 2030 of 30 percent of thermal production systems for buildings powered by biomass and electricity with more efficient systems according to Best Available Technology. (REEP07*_M02) Establishment of the Regional Energy Efficiency Fund for the promotion of energy efficiency actions in the domestic sector to reduce thermal energy consumption by at least 20 percent by 2030 compared to 2013. [. . .]

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