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Nature-based solutions and city planning: A study related to the preliminary Masterplan of Cagliari, Italy

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Abstract. The nature-based solutions are spatial planning measures implemented to restore and protect ecosystems and their capacity of supplying services, and to support the local communities, by leveraging on natural resources and enhancing the quality of natural contexts. The conceptual and technical methodological approach of this study considers nature-based solutions as urban planning tools aimed at mitigating heat waves, especially in densely urbanized areas, and at boosting several environmental, economic and social beneficial impacts thereof. A set of planning policies based on nature-based solutions are discussed as regards the definition of the preliminary Masterplan of Cagliari, the capital city of Sardinia, an Italian insular region. The nature-based solutions are identified with reference to the framework proposed by the European Environment Agency concerning adaptation to climate change and environmental risk reduction, which builds on a set of spatial profiles focused on water resources, forests and woodlands, agricultural production, urban areas and coastal zones.

Keywords: Nature-based solutions, Urban planning, City Masterplans.

1 Introduction[1]

Nature-based solutions (NBSs) leverage on infrastructure, building products and works which effectively use the services supplied by ecosystems to appropriately address and fix negative situations identified in the spatial organization of environmental contexts [6,8,13], with particular reference to climate change adaptation (CCA) and environmental risk reduction (ERR) thereof [2,10,11].

Climate-related hazard conditions are generally mitigated by the increase in resilience generated by exposure reduction, and by economic and social sensitivity to climate change-related events and to improvement in CCA [1]. For example, decrease in exposure can be associated to the ecosystems attitude towards rescuing with respect to extreme events. In this perspective, NBSs such as maintenance of alluvial areas and riverbeds can effectively operate through water retention by mitigating the environmental damage caused by floods. Increase in urban green areas can be associated to reduction in heat island-related negative impacts. The close relation between quality of life of the local societies and climate change effects can be positively affected by a proper management of land uses, which may possibly address adequately climate unpredictability [6]. For instance, the use of tree species and crops comparatively more resistant to water shortage is the most suitable in terms of diversification of income flows, both as regards forest and agricultural production. This implies that the local societies should improve their skills in terms of production techniques which implement CCA and ERR thereof [14].

NBSs aimed at reducing exposure and sensitivity to CCA-related hazard can be operationalized in several ways. Intervention modalities to increase the adaptive capacities of the local environments can be identified, such as protection and restoration of natural ecosystems located in context particularly valuable with reference to CCA, or management of ecosystems, such as agricultural areas and forests, which would provide a number of important services, if managed in function of appropriate differentiation, in order to increase their capacity of resistance to climate change impacts. Moreover, new natural ecosystems can be generated which supply CCA-related services, such as green roofs and walls, and hybrid solutions to coastal zone management [7].

This study focuses on the scientific and technical framework proposed by the European Environment Agency (EEA) concerning adaptation to climate change and ERR [6], which builds on a set of spatial profiles focused on water resources, forests and woodlands, agricultural production, urban areas and coastal zones. This framework is used to identify the systems of planning operations of the preliminary Masterplan of Cagliari (PMPC), which is presently being elaborated by the municipal administration of the Sardinian capital city.

The article develops as follows. The next section presents the methodology implemented to identify the NBSs suitable to be included in the PMPC; relevant contents of

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the cited Report of the EEA [6] are summarized as general references. Secondly, the specific objectives of the PMPC, identified in the Preliminary Environmental Report (PER), are associated to the systematized NBSs. Finally, the concluding section proposes a discussion on the future scientific and technical developments concerning NBSs-oriented urban planning processes.

2 Methodology

The PER starts with the identification of a system of environmental sustainability objectives associated to a set of environmental components which define the conceptual category of "environment," according to the provisions of Art. 5, paragraph 1, letter c), of Law enacted by legislative decree n. 2006/152. The environmental components are the following: air quality; water resources; waste management; soil; floristic and wildlife resources, and biodiversity; landscape, and historical and cultural heritage; settlements and demographic situation; public transportation and mobility; energy; noise.

The PER develops on the basis of the association of the sustainability objectives, identified with reference to each component through the environmental and SWOT analyses, with the specific objectives, put into effect through a system of planning measures.

Such system operationalizes the planning logical framework (LF) identified by the sustainability and specific objectives. The system of spatial interventions and transformations entailed by such planning measures implements the strategy of the PMPC and its spatial signs will become progressively more evident as long as the plan develops, particularly in the medium and long run. In the operational phase of the LF, the NBSs should be integrated in the set of the planning measures, as paradigmatic operations in the implementation process of the PMPC.

In this study, such integration is enacted in two sequentially related moments, as follows.

First, on the basis of the NBSs categories identified in the EEA's Report [6], a systematic layout of the NBSs connected with CCA and ERR is defined, as regards the spatial profiles identified by water resources, forests and woodlands, agricultural production, urban areas and coastal zones.

Secondly, the LF of the PMPC is set-up based on the PER, operationalized by the system of the specific objectives and of the planning measures [3]. Once the NBSs are identified, according to the EEA's categorization, and once the LF is defined, on the basis of the strategy and of the planning measures expressed in the PER of the PMPC, the implementation of the PMPC into NBSs implies that NBSs be included in the system of the planning measures and identified as the preferred planning choices among the alternatives concerning the possible planning measures to be undertaken, whenever possible.

3 Results

Tab. 1 reports the NBSs categorization according to the spatial profiles concerning water resources, forests and woodlands, agricultural production, urban areas and coastal zones. In the Table, each profile is synthetically featured by a few NBSs categories and by the supplied ecosystem services related to CCA, ERR and other benefits they provide the local communities with.

The second phase develops through the implementation of the specific objectives, identified in the PER in terms of a specification of the paradigm of sustainable development, into appropriate NBSs. Such implementation, shown in Tab. 2, associates the NBSs to the specific objectives in two ways: directly, if the specific objectives are straightforwardly connected with the NBSs they are implemented into; or, indirectly, if the NBSs associated to the specific objectives are likely to contribute to the objectives' targets even though they are not decisive, since a number of other non-NBS measures play relevant roles in their implementation. In both cases, the implementation of the specific objectives into selected NBSs would represent a strong attitude of the local planning authorities, which is the municipality of Cagliari in the case at stake, towards the preference for NBSs among the alternative planning measures. The specific objectives are identified in the PER of the PMPC [3]. Tab. 2 presents the association of the NBSs with the specific objectives related to the sustainability objectives concerning the environmental component "floristic and wildlife resources, and biodiversity," as a structured example of the application of the methodological approach described so far. Such approach can be straightforwardly used as regards the other environmental components listed in the second section.

Table 1. Categorization of the NBSs according to the five spatial profiles identified by the EEA (2021).

Spatial profile	NBSs	Ecosystem services
Water resources	Requalification and restoration of alluvial areas and riverbeds, also through forestry management	Floods control and mitigation
	Construction of systems aimed at harvesting rainwater, such as rain gardens, swales and bioswales, green roofs, walls and facades, and water collecting tanks	Improvement of habitats quality
	Construction of pervious superstructures and pavements for road infrastructure, parking areas, pedestrian ways and playgrounds	Control and mitigation of erosion and flood risk
	Permeabilization of impervious superstructures and pavements	Increase in the availability of outdoor recreational areas
		Reduction in the runoff speed during meteoric events of particular relevance and consequent mitigation of flood intensity
		Increase in groundwater recharge
		Mitigation of urban heat waves and of atmospheric warming in settlements through canopy and evapotranspiration
		Removal of soil pollutants through phytodepuration
Forests and woodlands	Protection of primary forests	Conservation and enhancement of biodiversity
	Plantation of new forests	Control and mitigation of erosion and flood
	Restoration of degraded forest systems	

Spatial profile	NBSs	Ecosystem services
	and woodlands	risk
	Sustainable management of primary forests, forest systems and woodlands	Reduction in the runoff speed during meteoric events of particular relevance and consequent mitigation of flood intensity
	Plantation of trees, tree rows, tree-lined areas and forests in urban areas	Increase in the availability of outdoor recreational areas and of landscapes of aesthetic value
		Qualitative improvement of soils
		Mitigation of urban heat waves and of atmospheric warming in settlements through canopy and evapotranspiration
		Increase in carbon dioxide capture and storage
Agricultural production	Improvement in water resources and soil management through cover crops, no-tillage or minimum tillage systems, management of high natural quality agricultural land, and enhancement of the irrigation systems efficiency	Decrease in the vulnerability of spatial contexts with reference to agricultural production
	Differentiation and rotation of crops, also through adapted crops, that is, crops which need comparatively less amount of water	Reduction in the runoff speed during meteoric events of particular relevance and consequent mitigation of flood intensity
	Plantation of agroforestry systems through differentiated land uses, where tree-lined areas, shrubs and productive crops are integrated in the same areal productive unit	Increase in groundwater recharge
	Plantation of agroforestry systems consisting of arable crops, surrounded by tree rows or windbreak hedges, or realized as zones characterized by promiscuous crops, with pastures and high-quality trees plantations, such as olive and fruit farming	Decrease in energy demand of pumping stations; decrease in carbon dioxide emissions
	New-generation agroforestry systems based on the combination of food and non-food biomass crops, which, for example, integrate poplar and locust tree groves with a number of crops	Decrease in the use of chemical fertilizers; increase in soils fertility
	Implementation of productive systems based on crop-livestock farming approaches, with reference to cattle breeding techniques, improvement of pastures, and forest and pasture practices	Enhancement of skillfulness concerning the economic management of rural areas through expert training on the integration of agriculture, breeding and tourism
	Implementation of water resources retrieval techniques, such as rainwater harvesting and groundwater recharging through systems implementing infiltration in the subsoil	
Urban areas	Requalification and restoration of alluvial areas and riverbeds, also through urban forestry management	Mitigation of urban heat waves and of atmospheric warming in settlements through canopy and evapotranspiration

Spatial profile	NBSs	Ecosystem services
	Plantation of trees, tree rows, tree-lined areas and forests in urban areas; efficient management of water resources through rainwater harvesting systems, such as rain gardens, swales and bioswales, green roofs, walls and facades, and water collection tanks	Reduction in the runoff speed during meteoric events of particular relevance and consequent mitigation of flood intensity
	Greening operations related to existing or new buildings, such as green roofs, walls and facades	Economic benefits to families, firms and local communities, such as increase in labor demand in the productive sectors related to NBSs, decrease in the private and social costs generated by environmental damages, and increase in land values due to the improved quality of the urban environments
	Implementation of water resources retrieval techniques, such as rainwater harvesting and groundwater recharging through systems implementing infiltration in the subsoil	Removal of soil pollutants through phytodepuration
	Construction of pervious superstructures and pavements for road infrastructure, parking areas, pedestrian ways and playgrounds	Increase in the social control over urban crime
	Permeabilization of impervious superstructures and pavements	Improvement in the urban transportation quality through efficient intermodal systems
		Increase in carbon dioxide capture and storage
		Increase in biodiversity due to new ecosystems generated by green roofs, walls and facades
Coastal zones	Protection and restoration of terrestrial coastal habitats, with reference to coastal and dunal vegetation	Sedimentary retention and mitigation of erosion
	Protection and enhancement of sea grasses	Protection from sea level rise, storm waves and surges
	Protection and enhancement of coral reefs	Control and mitigation of erosion and flood risk
	Protection and enhancement of transition waters, such as estuaries and mouths of rivers, and coastal wetlands	Increase in the availability of outdoor recreational areas
	Protection and enhancement of coastal areas immediately adjacent to the coastline, through barrier islands, reconstitution of the dune, natural or artificial beach nourishment also through advanced technologies such as the "Sand Motor," green dykes, wooden barriers and vegetated banks	Increase in carbon dioxide capture and storage
	Stabilization of high rocky shores through vegetation	

Tab. 2 shows how to implement the LF, defined by the PER, into sets of NBSs, conceived as technical operational approaches to reach the targets set by the specific objectives. Tab. 2 reports the results related to two specific objectives referred to the environmental component "Floristic and wildlife resources, and biodiversity", that is,

"Restoration and increase in the quality of agricultural areas" and "Regeneration of the existing urban settlements and of the waterfronts".[2]

The key issue is therefore how to define NBSs so as to maximize their effectiveness in addressing the specific objectives identified by the LF of the PMPC, through their inclusion in the statutory code of the Masterplan. This is a fundamental question, not only in order to operationalize the NBSs into the implementation of the PMPC, but also to ensure that the targets set by the specific objective be addressed, whenever possible, exclusively through NBSs.

This can be done by including in the plan's statutory code a set of rules which explicitly associate a system of NBSs with the implementation of the land use regulations established by the code. This implies a structured and detailed planning vision, collaboratively shared between public decision makers, public and private stakeholders, and the local communities, as regards the plan's implementation process, with particular reference to the prescriptive character of the adopted NBSs and the entailed restrictions on private property rights.

Table 2. Assessment of the specific objectives of the PMPC with reference to their implementability through NBSs, as regards two selected specific objectives referred to the environmental component "Floristic and wildlife resources, and biodiversity."

Specific objectives	Directly associated NBSs	Indirectly associated NBSs
Restoration and increase in the quality of agricultural areas	Improvement in water resources and soil management through cover crops, no-tillage or minimum tillage systems, management of high natural quality agricultural land, and enhancement of the irrigation systems efficiency	Requalification and restoration of alluvial areas and riverbeds, also through urban forestry management
		Protection of primary forests
		Plantation of new forests
	Differentiation and rotation of crops, also through adapted crops, that is, crops which need comparatively less amount of water	Restoration of degraded forest systems and woodlands
		Sustainable management of primary forests, forest systems and woodlands
	Plantation of agroforestry systems through differentiated land uses, where tree-lined areas, shrubs and productive crops are integrated in the same areal productive unit	Plantation of trees, tree rows, tree-lined areas and forests in urban areas
	Plantation of agroforestry systems consisting of arable crops, surrounded by tree rows or windbreak hedges, or realized as zones characterized by promiscuous crops, with pastures and high	Implementation of water resources retrieval techniques, such as rainwater harvesting and groundwater recharging through systems implementing infiltration in the subsoil

[2] The complete set of the specific objectives of such environmental component also includes the following: "Preservation of the environmental and natural integrity of protected areas and increase in the landscape quality of targeted spatial contexts", "Conservation and protection of the geological value of spatial contexts, and of the natural integrity of coastal areas", "Increase in urban forests and woodlands, and in biodiversity; protection of indigenous species and restoration of ecological connections", "Enhancement in the protection systems of coastal areas", and "Improvement in quality of waterbodies and groundwater".

Specific objectives	Directly associated NBSs	Indirectly associated NBSs
	quality trees plantations, such as olive and fruit farming New-generation agroforestry systems based on the combination of food and non-food biomass crops, which, for example, integrate poplar and locust tree groves with a number of crops; implementation of productive systems based on crop-livestock farming approaches, with reference to cattle breeding techniques, improvement of pastures, and forest and pasture practices Implementation of productive systems based on crop-livestock farming approaches, with reference to cattle breeding techniques, improvement of pastures, and forest and pasture practices	
Regeneration of the existing urban settlements and of the waterfronts	Greening operations related to existing or new buildings, such as green roofs, walls and facades Implementation of water resources retrieval techniques, such as rainwater harvesting and groundwater recharging through systems implementing infiltration in the subsoil Construction of pervious superstructures and pavements for road infrastructure, parking areas, pedestrian ways and playgrounds Permeabilization of impervious superstructures and pavements	Requalification and restoration of alluvial areas and riverbeds, also through urban forestry management Plantation of trees, tree rows, tree-lined areas and forests in urban areas Construction of systems aimed at harvesting rainwater, such as rain gardens, swales and bioswales, green roofs, walls and facades, and water collecting tanks

4 Discussion and conclusions

A viable route to include in the plan's statutory code a set of rules which explicitly associate a system of NBSs with the implementation of the land use regulations can be based on the establishment of project worksheets as statutory rules, integrated in the planning code, which should state in detail how to implement each of the NBSs identified to address the specific objectives defined in the LF of the PMPC. The establishment of such project worksheets is a consolidated approach, shared between several masterplans of Italian cities and towns, and widely described and discussed in the scientific and technical literature.

A significant example of the use of such project worksheets is represented by the Masterplan of Trieste [12]. In such Masterplan, the project worksheet approach is used on a large spatial scale, with particular reference to the "areas targeted for radical

spatial transformations," to the "urban regeneration zones," to the "areas targeted for urban renewal," and to the "new city of gardens." According to the Masterplan of Trieste, the project worksheets concern "Areas and subareas […] identified through the delimitation of the urban zones at stake and further sub-divided in parts according to the statements of the project worksheets.

Unless otherwise specified (such specifications have to be contained in the worksheets), graphic indications are not prescriptive, whereas the main project elements, the quantitative parameters, the implementation procedures and the rules concerning land uses are legally binding" [12, p. 3]. Among the "main project elements," the quantitative parameters, the urbanization works and the urban planning-related ecological parameters are stated, identified by the permeability rate, the density of trees and shrubs, which should be integrated with the public services framework in the different urban sectors, their endowments, the planned interventions on the existing settlements and the planned settlement expansion.

The mandatory character of the project worksheets as regards the NBSs, entailed by the Masterplan of Trieste, implies a thorough technical detail so as to make the project rules as binding as possible in order to grant the effectiveness of their implementation.

However, the planning approach based on the project worksheets, which can be made operational in the ordinary spatial planning practices without any legislative addition, entails in-depth skills as regards the NBSs to be implemented, not only with reference to project technologies, but also, and perhaps above all, as regards financial aspects, turnaround time, and trained personnel needed to manage the operational phases of the project implementation.

Such technical expertise is not rooted yet in the offices of the local public administrations, especially in small municipalities. It would be therefore necessary to implement an innovative expertise into the technical officers of such administrations in order to increase their acquaintance with NBSs so as to embed them into public spatial planning practices. Such Copernican revolution would entail a strong deliberateness, on behalf of the national and the regional governments, towards targeting huge public investment in high-level training of administrative and technical executives of the public bodies.

Moreover, it has to be highlighted that NBSs are still a novel approach, even though their use can be identified in several spatial planning measures and project-oriented operational experiences and, that being so, their integration into practice implies progressive and complex further analysis and assessment, particularly in relation to a number of caveats which make quite problematic their implementation on a large spatial scale. Such caveats frequently make the public administrations quite reluctant towards NBSs and their use as a comprehensive and effective approach to spatial planning, especially small municipalities whose officers are comparatively less trained with respect to the technical skills needed to plan and project NBSs.

Finally, as regards promising future research developments, it is importantto report some of the issues presented and discussed in the EEA's Report which assess relevant questions related to the NBSs solutions concerning CCA and ERR [6, p. 73]. The following points identify these issues, proposed in the EEA's Report as calls for going

on along the scientific and technical path traced by the NBSs-based conceptual approach:

- meteorological and climate-related events connected with climate change are particularly influential at the large spatial scale, and their impacts are not limited by geographic, administrative, social or economic boundaries; as a consequence, scientific and technical research on NBSs and their implementation should be integrated into spatial planning policies across local, regional and national contexts, in order to maximize their value added;
- taking account of the considerable number of positive impacts generated by NBSs, they should be strategically implemented so as to involve many development objectives, with particular reference to the sustainable development goals of the Agenda 2030 of the United Nations;
- it would be necessary to integrate and operationalize NBSs in public planning practice at the different spatial scales, and to develop network organizations aimed at fostering collaborative interdisciplinary approaches based on interregional coordination;
- integrating and operationalizing NBSs concerning CCA and ERR in public planning practice implies identification and use of high-quality technical standards in their definition, effective implementation of the subsidiarity principle in their management, significant improvement in the expertise of the involved public administrations, and availability of adequate financial resources;
- a relevant increase in technical expertise is necessary as regards the integration of green and grey infrastructures;
- the stakeholders affected by the implementation of public policies based on NBSs aimed at dealing with CCA and ERR should be proactively involved in the related planning phases in order to encourage consensus-building and, by doing so, to help minimizing the outbreak of conflicts;
- the implementation of NBSs-based projects which involve aesthetic profiles should be particularly accurate so as to contribute to generating a positive mood towards their use;
- adequate systems of databases and indicators, based on sound scientific and technical research, should be identified in order to monitor and drive the implementation of NBSs, particularly with reference to the numerous benefits generated in terms of CCA and ERR;
- suitable methodologies should be identified to detect the quantitative profile of NBSs, as regards their environmental, social, cultural and economic implications;
- the interoperability issue is particularly relevant with reference to systems of databases and indicators concerning the quantification of benefits generated by NBSs aimed at dealing with CCA and ERR, since assessments based on comparisons between NBSs implemented in different administrative spatial contexts, possibly located in different countries, would be of great interest to policy makers;
- it is crucial that the definition of long-run strategies, associated with processes whose operational results are expected to occur in the long term, such as increase in the air temperature or biodiversity loss, be implemented by giving particular at-

tention to the interaction of the numerous factors which influence such processes, for example public health, food safety, water resources availability and ecosystems resilience.

The points reported above are basically related to the experience of the EU countries with reference to the use of NBSs in spatial planning processes aimed at addressing CCA and ERR, which originates from the Final Report of the Horizon 2020 Expert Group on Nature-Based Solutions and Re-Naturing Cities [4]. Based on this Report, a number of experimental projects were financed through the Horizon 2020 Program, on the ground that they implemented best practices straightforwardly exportable across the EU countries and through time [5]. La Rosa et al. claim that the European Commission (EC) approach to projects selection tends towards prioritizing the following features [9, p. 330]:

- use, promotion and enhancement of natural ecosystems is a key issue;
- produced or refunctionalized green infrastructures generate positive impacts in ecological, social cultural and economic terms;
- produced or refunctionalized green infrastructures integrate characteristics and processes based on natural resources within urban settlements and communities;
- ecosystem services, provided by such green infrastructures, are strictly related to expectations and perceived needs of the local societies, and are characterized by their efficiency and effectiveness in addressing the numerous goals and visions of such social contexts;
- NBSs and the green infrastructures coming from their implementation preserve their capacity of providing ecosystem services in the long run.

The theoretical and technical position of La Rosa et al. [9] as regards the definition and implementation of NBSs-based projects is that it is high time to identify exportable good social and ecological practices on the basis of projects implemented in different spatial contexts across countries and through time, even in the long run, featured by problem-solving approaches, rather than by making reference to demonstration projects financed by the Horizon 2020 Program. The former represent spontaneous and direct measures which address real problems identified by the local societies, whereas the latter are set in the somehow abstract frames structured under the provisions of the Horizon 2020 rules; the implementation of the former is not subject to time limits as it occurs in the case of the latter, which have to meet rigid deadlines; finally, the non-Horizon NBSs-based projects are characterized by a continuous fine-tuning, which features their true experimental attitude.

Certainly, the approach to NBSs supported by La Rosa et al. and the demonstration projects financed by the EC show a strong subsidiarity and represents relevant perspectives for future research on NBSs implemented into public planning processes.

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