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Inclusion of natural areas in a holistic resilience assessment framework

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ABSTRACT

A holistic resilience assessment in an urban area or region identifies the opportunities and priorities for enhancing resilience, namely when interacting services and infrastructure are considered.

The mitigation of climate change impacts due to natural areas have been highlighted in several studies. This happens in either natural areas already existing or in man-made nature-based solutions within urban environments. For a holistic assessment of resilience, considering natural areas like any other urban service (e.g. water supply, stormwater drainage) has several advantages, such as the recognition of existing interdependencies and the use of a common evaluation structure for the various services provided by the same organization (e.g. a municipality).

A resilience assessment framework and tool are being developed within ICARIA (Improving ClimAte Resilience of crItical Assets). This paper presents the ICARIA project and the methodology for extending the ICARIA Resilience Assessment Framework (RAF). The focus is on the approach and scope used to include natural areas as a service, a multi-benefit service provided by cities or regions to their citizens, workers, and tourists. A first glimpse into how the RAF is being developed, namely a preliminary version of the assessment objectives and criteria, is presented.

1. Introduction

Urban resilience describes the ability of human settlements to withstand, recover quickly and adapt from any plausible hazards, both for acute shocks and slower changes in circumstances (UN-Habitat, 2018; UNDRR, 2017a and b; ARUP, 2105). Resilience to disruptive events comprises reducing risks and damage from disasters, and the capacities to withstand and to rapidly bounce back to a stable state. A resilience assessment is required to identify the opportunities and priorities for enhancing urban resilience. Assessing the current and expected future status of resilience is a basis for cities and regions to know where they are, where they want to be and how to get there. Resilience assessment identifies the resilience strengths and weaknesses, supports the planning for action in the long, medium, and short term and assists in evaluating progress in between (Cardoso et al., 2020a).

A resilience assessment framework and webtool are being upgraded and broadened within ICARIA project (Improving ClimAte Resilience of crItical Assets, https://www.icaria-project.eu/).

The ICARIA project belongs to the Mission “Adaptation to climate change” of the research funding program Horizon Europe. The overall aim of the Mission is to support European regions to become climate resilient.

ICARIA aims to achieve a better understanding of climate change related impacts and adaptation measures on critical assets (Russo et al., 2023).

The ICARIA project builds upon existing single-hazard methodologies to develop a quantitative multi-hazard risk assessment framework. The output of this ICARIA framework will be information on tangible impacts, specific for each hazard, asset or service considered, represented in risk distribution maps and by quantitative data sets. Cascading effects (from single and compound events) are being considered, and multi-hazard and multi-risk assessment are being incorporated. The results of modelling tools, along with data on governance, socio-economic aspects, spatial planning, and service management, contribute to a holistic infrastructure resilience assessment, with the possibility to focus on critical infrastructure. The holistic resilience assessments will be performed for selected hazards and scenarios. Later, an end-user-oriented Decision Support System (DSS) toolbox, to plan the most cost-efficient adaptation measures, will be developed.

Resilience assessment considers that assets and services with different functions coexist in time and space. Their performance is interlinked, in everyday life, and even more while enduring disruptive events (Brugmann, 2012). The ICARIA RAF builds on existing frameworks and app. These are from the RESCCUE project (Velasco et al., 2020), the RESCCUE RAF (Cardoso et al., 2020a) and the RESCCUE RAF App (Lopes et al., 2019), and from the EU-CIRCLE project, the RAT tool (Katopodis et al., 2018).

The ICARIA RAF was developed to: i) extend the city-wide assessment to address a regional scope; ii) include complementary assets beyond those already covered (such as those from water services, waste, energy, and mobility), namely natural areas; and iii) diagnose additional hazards beyond those already covered (flooding, storm surge, heat waves, drought, and windstorms), namely forest fires.

2. Methods

2.1. Main steps

The inclusion of natural areas in the ICARIA RAF comprised the steps represented in Fig.1. The current paper is focused on the scope and the approach steps.

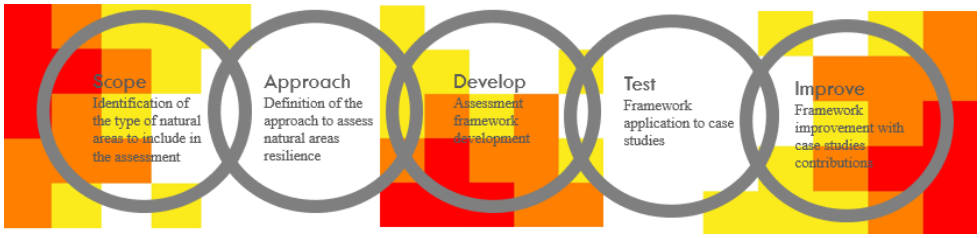

Fig. 1. Methodology to include natural areas in a resilience assessment framework.

2.2. Scope

Natural areas, both native and constructed grey-blue-green infrastructure, either in a large or small scale, comprise large reserves, forests, rivers, urban streams, urban parks, and urban nature-based solutions (NBS) such as infiltration basins, green roofs and walls, vegetated swales, infiltration trenches, or porous pavements. NBS are man-made solutions "inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience" (EC, 2021).

Protected areas and forests are mostly native or have long existed. Urban parks, ponds, lakes, tree lines or vegetated squares were frequently designed and implemented to address a specific problem (environmental or urbanistic) but still provide several other co-benefits.

In a resilience assessment, from a holistic point of view, it is advantageous to include both NBS and other existing natural areas, to account for all the integrated co-benefits. Integrating all natural areas in a framework comprising other urban services enables including the existing interdependencies between the blue-green areas and the other services, such as water supply, stormwater, or mobility. Moreover, using a common assessment structure facilitates the interpretation and communication of results, in an organization that is responsible for several services (e.g. a municipality), which enables the identification of potential synergies (e.g., water reuse for irrigation).

2.3. Approach

Despite being or not designed and implemented with the purpose to address climate change challenges, several studies have highlighted the importance of mitigation of climate change impacts due to natural areas. Some

studies are focused on the urban heat island mitigation and stormwater management as potential benefits of the natural areas (Almaaitah et al., 2021). Others have a more holistic approach, either by detailing the multiple ecosystem services that are provided, by addressing socio-economic challenges (Beceiro et al., 2020; Sarabi et al., 2019; Cardinali et al., 2023), or by embracing other hazards, such as earthquakes, fires, or hurricanes (EC, 2021).

The UN-Habitat resilience approach (UNHabitat, 2018) is comprehensive and provides both an overview of the city resilience as a whole and the resilience of each service in specific, by considering the following resilience dimensions: organisational (on governance), spatial (on urban space and environment), functional (on the strategic services) and physical (on the infrastructure of the services). The first two dimensions are mainly addressed by the city or regional administration, and the last two are addressed by the service providers.

These dimensions were used in the RESCCUE project, considering the urban services of water supply, wastewater, storm water and solid waste management, electrical energy provision, and mobility (Cardoso et al, 2020b). In each dimension, a hierarchical tree structure (objectives-criteria-metrics) is adopted for assessment (Cardoso et al, 2020a).

2.4. Development

The ICARIA resilience assessment framework (ICARIA RAF) has, similarly, a hierarchical tree structure. For each dimension, resilience objectives are defined, representing the ambitions to be achieved in the medium–long term by the city/region and by the services. Each objective unfolds into a set of criteria, that translate the different points of view associated with it. Each criterion assembles the respective assessment metrics. Metrics consist of questions, parameters or functions used to assess the criteria.

Some of the ICARIA RAF objectives, criteria and metrics correspond to (or were adapted from) existing frameworks, mainly from UNDRR framework (former UNISDR) and the RESCCUE project, found to be strongly linked to the ICARIA project. Other objectives, criteria and metrics were newly developed within the project.

As urban resilience considers the city's ability to absorb disturbances, learn from the past, adapt, transform, and prepare for the future, the RAF contents address these five resilience capabilities - namely, absorb, learn, adapt, transform, and prepare.

2.5. Testing and improvement

Testing of the ICARIA RAF module on natural areas will be performed in a two-stage process. Firstly, the proposed dimensions, resilience objectives, criteria, and metrics will be analysed with the stakeholders during working sessions and a survey will be conducted to determine the RAF metrics' relevance and the feasibility of application to their own cities. This will enable the identification of knowledge gaps and improvement opportunities for the framework. Secondly, the metrics will be answered for the case studies, taking into consideration the available information. This will also enable the identification of knowledge gaps and improvement opportunities, as well as the effectiveness of the framework to assess resilience.

3. Results

In the ICARIA RAF, natural areas are considered as a service, a complementary and region-wide service provided by local authorities, in line with the UN-Habitat and RESCCUE approaches. This way forward has the advantage of disaggregating the contribution of diverse services and assets to the overall resilience. For example, the functional dimension considers service planning and risk management, and its preparedness to respond, endure and build back from stressful climate change events. From the infrastructural point of view, the physical dimension considers how safe, robust, and prepared for climate change the natural assets are, incorporating the interdependencies with assets from other services.

The consideration of natural areas as a service is also supported by the fact that a healthy natural environment provides a range of benefits, such as drinking water or clean air. The benefits that humans derive from nature are known as ecosystem services. They can be structured into four categories: provisioning services, regulating services, habitat or supporting services, and cultural services (Millennium Ecosystem assessment 2005; TEEB, 2011). Fig. 2 presents a detail on ecosystem services categories, namely those relevant to cities.

Almost every resource that societies use daily relies, directly or indirectly, on ecosystem services, either for human wellbeing or economic activities. Thus, healthy natural areas must be a concern for all. A degraded natural area will cease to supply the ecosystem services that societies rely upon, and it can be extremely

expensive, time-consuming, or even impossible to restore the ecosystems. For that reason, incorporating natural areas in city management is possible to be done and extremely beneficial (TEEB, 2011), and their condition ought to be monitored and maintained. Ecosystem services are, therefore, a core topic in natural areas' assessments.

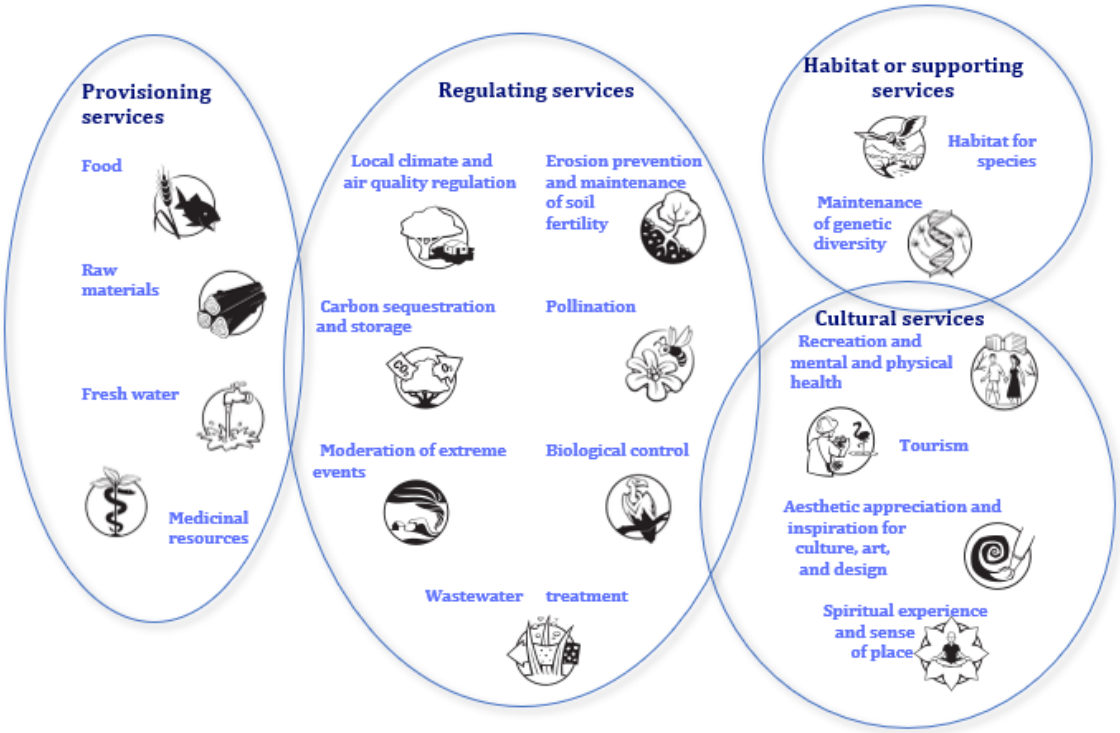

Fig. 2. Ecosystem services categories relevant to cities (based on TEEB, 2011)

The preliminary version of the ICARIA RAF module on natural areas is currently developed and being tested.

In the spatial dimension, 3 metrics were revised, and 4 new metrics were included.

The inclusion of the natural areas as a service was mostly accomplished in the functional and physical dimensions. Both dimensions address the five resilience capabilities. The ICARIA RAF considers the time scale by integrating past experience (assessing the impact of a historical event with characteristics similar to the scenarios), the current situation (assessing the impact of everyday life, by assessing a year without historical events in the records), and future situation (regarding climate change scenarios). This preliminary version of the framework will be applied to case studies for feedback.

Table 1 presents an overview of the ICARIA RAF functional dimension, its objectives, and criteria for natural areas.

Table 1. Overview of ICARIA RAF functional dimension for natural areas

OBJECTIVE	CRITERION
SERVICE PLANNING AND RISK MANAGEMENT	Strategic planning
	Resilience engaged service
	Risk management
	Reliable service
	Flexible service
AUTONOMOUS SERVICE	Natural areas' service importance
	Natural areas inter-dependency with other services considering climate change
SERVICE PREPAREDNESS	Service preparedness for disaster response
	Service preparedness for climate change
	Service preparedness for recovery and build back

This dimension relates to the way the service is organized and its resilience commitment and maturity. In this dimension, the resilience objectives aim to ensure that the natural services are properly planned and managed, that their autonomy is guaranteed, and that they are prepared for climate change challenges. This dimension

also allows to identify the contribution of the natural areas to city and regional resilience. Natural area's services are assessed as ecosystem services, namely: health and well-being, biodiversity, aesthetical and recreational activities, groundwater recharge, temperature reduction, air quality, carbon sequestration and storage, enhanced infiltration, water retention and evapotranspiration, regeneration of abandoned areas, and land slide and erosion prevention. These are assessed within the "resilience engaged service" criterium. There is also an assessment on whether the existing and planned ecosystem services meet the expectations for the area, in the "strategic planning" criterium. The connection with the water services is accessed in the "flexible service" criterium, namely in what regards water uses and water reuse.

The past experience is considered within the "service preparedness for recovery and buildback". The current situation, within the "reliable service". The future situation is considered within the "risk management" criterium.

Table 2 presents an overview of the RAF physical dimension, its objectives, and criteria for natural areas.

Table 2. Overview of RAF physical dimension for natural areas

OBJECTIVE	CRITERION
SAFE INFRASTRUCTURE	Infrastructure assets criticality and protection
	Infrastructure assets robustness
AUTONOMOUS AND FLEXIBLE INFRASTRUCTURE	Infrastructure assets importance to and dependency on other services
	Infrastructure assets autonomy
	Infrastructure assets redundancy
INFRASTRUCTURE PREPAREDNESS	Contribution to the area's resilience
	Infrastructure assets exposure to climate change
	Preparedness for climate change
	Preparedness for recovery and buildback

This dimension relates to assets safety, autonomy, and redundancy. In this dimension, the resilience objectives aim to ensure that the natural assets (forests, green roofs, lakes, …) that provide the service are safe, properly maintained and monitored, autonomous and flexible, and prepared for climate change challenges, namely in what regards to ecosystem services. This dimension also allows knowing the contribution of natural areas' assets to the resilience of both the respective service and of the city(ies) and region. The connection with the water supply is assessed in "infrastructure assets autonomy", namely the natural areas autonomy and water self-sufficiency.

The past experience is considered within the "preparedness for recovery and buildback". The current situation, within the "infrastructure assets robustness". The future situation is considered within the "infrastructure assets exposure to climate change" criterium.

The construction of the resilience metrics for the natural areas is ongoing, which will provide a deeper detail on the resilience aspects to be analyzed. Each metric will be evaluated by comparing its answer with reference values, established for incipient, progressing, or advanced resilience, thus providing an indication of the development level.

4. Final remarks

A resilience assessment framework is presented, regarding the upgrade and extension considered within the ICARIA project to include a regional scope in the assessment, the natural areas as a service, and additional hazards, namely forest fires. In a resilience assessment, from a holistic point of view, inclusion of NBS and other existing natural areas allows to account for all the integrated co-benefits, as well as interdependencies between the natural areas and the other services.

The ICARIA RAF for natural areas is to be tested, to analyse metrics' relevance and its feasibility of application, as well as the effectiveness of the framework to assess resilience considering this important service.

Acknowledgments

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