Alma Mater Studiorum - Università di Bologna

DOTTORATO DI RICERCA IN

ARCHITETTURA E CULTURE DEL PROGETTO

Ciclo 33

Settore Concorsuale: 08/F1 - PIANIFICAZIONE E PROGETTAZIONE URBANISTICA E TERRITORIALE

Settore Scientifico Disciplinare: ICAR/20 - TECNICA E PIANIFICAZIONE URBANISTICA

GREENING THE CITY: AN ECOSYSTEM-BASED FRAMEWORK TO SUPPORT PLANNING TOWARDS URBAN SUSTAINABILITY AND RESILIENCE

Presentata da: Claudia De Luca

Coordinatore Dottorato

Annalisa Trentin

Supervisore

Simona Tondelli

Cosupervisore

John Martin

Esame finale anno 2021

CONTENTS

ABSTRACT

Cities are small-scale complex socio-ecological systems, that host around 60% of world population. Ecosystem Services (ES) provided by urban ecosystems offer multiple benefits necessary to cope with present and future urban challenges. These ES include microclimate regulation, runoff control, as well as opportunities for mental and physical recreation, affecting citizen's health and wellbeing. Creating a balance between urban development, land take containment, climate adaptation and availability of Urban Green Areas and their related benefits, can improve the quality of the lives of the inhabitants, the economic performance of the city and the social justice and cohesion aspects.

This work starts analysing current literature around the topic of Ecosystem Services (ES), Green and Blue Infrastructure (GBI) and Nature-based Solutions (NBS) and their integration within current European and International sustainability policies. Then, the thesis focuses on the role of ES, GBI and NBS towards urban sustainability and resilience setting the basis to build the core methodological and conceptual approach of this work. The developed ES-based conceptual approach provides guidance on how to map and assess ES, to better inform policy making and to give the proper value to ES within urban context. The proposed interdisciplinary approach navigates the topic of mapping and assessing ES benefits in terms of regulatory services, with a focus on climate mitigation and adaptation, and cultural services, to enhance wellbeing and justice in urban areas. Last, this thesis proposes a transdisciplinary and participatory approach to build resilience over time around all relevant urban ES. The two case studies that will be presented in this dissertation, the city of Bologna and the city of Barcelona, have been used to implement, tailor and test the proposed conceptual framework, raising valuable inputs for planning, policies and science.

GLOSSARY

CITIES AS SOCIO ECOLOGICAL SYSTEMS (SES)

Cities should be understood as (1) complex, adaptive systems that are (2) integrated across spheres of matter, life and human social and cultural phenomena (or mind), (3) are structured as nested systems that allows interaction across scales and levels of organisation, and (4) that what differentiates cities (and SESs) from other types of ecosystems is the introduction of abstract thought and symbolic construction that allows for considered novelty, communication of ideas across time and space, and therefore learning, and reflexive thinking (du Plessis, 2008)

ECOSYSTEM-BASED ADAPTATION (EBA)

Adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach. EBA involves national and regional governments, local communities, private companies and NGOs in addressing the different pressures on ecosystem services, including land use change and climate change, and managing ecosystems to increase the resilience of people and economic sectors to climate change (Vignola, Locatelli, Martinez, & Imbach, 2009).

ECOSYSTEM SERVICES (ES)

Ecosystem Services are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems (Costanza et al., 1997). An approach to understand how natural systems can benefit humans, by linkages between ecosystem structures and process functioning and consequent outcomes which lead directly or indirectly to valued human welfare benefits (gains or losses) (Turner and Daily 2008).

ES CAPACITY

The ecosystem's potential to deliver ES based on its structures, processes and functions under the current management of the ecosystem'(Villamagna et al., 2013).

ES DEMAND

The amount of ecosystem services required or desired by society (Villamagna et al., 2013).

ECOSYSTEM SERVICES FLOW

The Ecosystem services actually received, used or experienced by people", (Villamagna et al., 2013).

ECOSYSTEM SERVICES SUPPLY

ES supply within the city is made by its biodiversity (Gómez-Baggethun et al. 2014) and ecosystem structure (Potschin and Haines-Young 2011)

GREEN AND BLUE INFRASTRUCTURES (GBI)

A strategically planned and managed, spatially interconnected network of multi-functional natural, semi-natural and man-made green and blue features including agricultural land, green corridors, urban parks, forest reserves, wetlands, rivers, coastal and other aquatic ecosystems (European Commission, 2013)

NATURE BASED SOLUTIONS (NBS)

Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions (European Commission, 2015)

NATURAL CAPITAL

Natural capital is the stock of living and non-living parts of the natural system that XXX

NATURAL WATER RETENTION MEASURES

Natural water retention measures are measures that aim to safeguard and enhance the water storage potential of landscape, soil, and aquifers, by restoring ecosystems, natural features and characteristics of water courses and using natural processes. They support Green Infrastructure by contributing to integrated goals dealing with nature and biodiversity conservation and restoration, landscaping, etc. They are adaptation measures that use nature to regulate the flow and transport of water so as to smooth peaks and moderate extreme events (floods, droughts, desertification, salination). They are a better environmental option for flood risk management (European Commission, 2012)

URBAN RESILIENCE

Ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity' (Meerow et al., 2016)

LIST OF FIGURES AND TABLES

1 INTRODUCTION

It is now widely recognized that human activities have reached a level that could result in abrupt and, in some cases, irreversible environmental changes detrimental to human development (Eggermont et al., 2015) and significantly affecting Earth natural processes, ecosystems and functions (Steffen et al., 2018). The idea that human activities, although terribly brief on geological timescales, may nevertheless have had geologically significant and long-lasting effects, grew during the 20th century and it was then recognized through the evolution of the *Anthropocene* concept from the beginning of the 21st century (Crutzen, 2002).

The current trend of natural resources' overexploitation (Lampert, 2019), ecosystem deterioration and pollution, biodiversity loss (UNCBD, 2020), increasing population (UN, 2018) and climate changes (IPCC, 2014) also drove scientists to reflect on earth system carrying capacity, limits and boundaries. In this direction Rockström et al. 2009 introduced a novel concept, the so-called planetary boundaries, *for estimating a safe operating space for humanity with respect to the functioning of the Earth System*. Specifically, nine planetary boundaries that *should not be transgressed if we are to avoid unacceptable global environmental change*, have been identified and tentatively quantified. These boundaries include climate change, biogeochemical flows, ocean acidification, stratospheric ozone depletion, novel entities, biosphere integrity, land-system change and global freshwater use. These boundaries are strictly related with associated tipping points or elements. The term "tipping point" commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system (Lenton et al., 2008). Most of the planetary boundaries identified are influenced by complex dynamic interactions, making specific tipping points difficult to define. Indeed, whether ozone depletion can be considered a rather linear issue, being created by specific chemicals introduced by anthropic activities, other boundaries related to climate change, biosphere integrity and land-system change are influenced by non-linear and dynamic aspects raising from complex socio-ecological adaptive system.

The bio-physical boundaries set up by Rockström et al. 2009 specifically focused on ecological thresholds and dangerous aggregate effects. At the same time, we cannot overlook at the social component, part of the same complex socio-ecological system that Rockström is framing.

Human wellbeing depends fundamentally upon each person having claim to the natural resources required to meet their physiological needs such as food, water, shelter and sanitation (Dearing et al., 2014). It follows from these fundamental equity considerations *that social foundations should be considered alongside planetary and regional boundaries*.

Along with ecological and bio-physical tipping points, boundaries and carrying capacity elements, we need a better understanding of human drivers of change and social distributional issues including transdisciplinary, conceptual and ethical challenges to the planetary boundaries concept (Dearing et al. 2014). At different scale national governments, cities and local authorities face a major challenge in achieving wellbeing for all, while simultaneously ensuring the sustainability of processes and services that underpin wellbeing (Dearing et al. 2014).

From the beginning of the 20th century and at a tremendously fast-growing rate starting from the second world war, industrialization, urbanization, and land use changes are profoundly altering the relationship between human settlements, societies and ecosystems, affecting their functions and services. Urbanization has become one of the most important issues which define the human relationship with the ecosystem (Verma & Raghubanshi, 2018) and the interaction of pressures caused by urban sprawl are causing an impact on the environment that goes much beyond the city and its surrounding areas (Frank, 2017). Urban areas can be considered as an agglomeration of socio-economic systems, including a range of 'urban services' such as housing, health, education, transport, and jobs, and ecological systems, benefiting from a range of ecosystem services, such as freshwater and food provision, micro-climate regulation, carbon storage, air filtration and recreation and health values (Ernstson, 2013). With around 60% of world population living in cities (Güneralp et al., 2017; UN, 2018), the achievement of global sustainable development goals, subject to planetary boundaries, will mostly be determined by cities as they drive cultures, economies and use of resources (Hoornweg, Hosseini, Kennedy, & Behdadi, 2016). Cities are both the source of and solution to today's economic, environmental, and social challenges.

Europe's urban areas are home to over two-thirds of the EU's population, they account for about 80 % of energy use and generate up to 85 % of Europe's GDP. These urban areas embed a fertile ground for innovation, since they host knowledge hubs nurtured by different stakeholders– universities, local authorities, citizens' associations, NGOs and enterprises. But they are also the places where persistent problems, such as unemployment, segregation and poverty, are at their most severe. Social and health related challenges are central to urban areas as well as ecological and environmental related issues.

Urban ecosystem services (ES) provided by nature and urban ecosystems offer multiple benefits necessary to cope with present and future urban challenges (Costanza et al., 1997; Gascon et al., 2015; Gómez-Baggethun & Barton, 2013). These ES include microclimate regulation, runoff control, as well as opportunities for mental and physical recreation, affecting citizen's health and wellbeing (Haase et al., 2014). Long-term urban policies and strategies can play a central role in maintaining and increasing ES toward more sustainable, liveable and resilient cities (Ahern, Cilliers, & Niemelä, 2014). Sustainability and resilience have become key concepts aimed at understanding existing urban dynamics and responding to the challenges of creating liveable urban futures (Romero-Lankao, Gnatz, Wilhelmi, & Hayden, 2016). Sustainable urban planning, as also underlined by the New Urban Agenda (UN, 2016), assumes a crucial importance in the development of sustainable cities. However, current urban strategies are often overlooking the dynamic character of cities and the pivotal role nature plays for sustainable urban transformation and the creation of resilience around human wellbeing (Langemeyer, Gómez-Baggethun, Haase, Scheuer, & Elmqvist, 2016; McPhearson et al., 2016).

Ecosystem service models and planning approach provide important tools to facilitate urban, national and regional decision-making by assessing ecosystem services supply, flow and demand (Geijzendorffer, Martín-López, & Roche, 2015; Haase et al., 2014; Syrbe & Grunewald, 2017). IPBES has reviewed and summarized existing modelling tools to guide regional, global and thematic assessments as well as outlining best-practices for policy-makers in the use of these tools (IPBES, 2016). However, guidance on how, where and when ecosystems and their services should be managed to deliver on specific and/or multiple benefits to citizens remains poorly articulated and difficult for policymakers to incorporate into local policies and plans. Moreover, cities are increasingly struggling to understand and assess the effectiveness of compact-city against urban-sprawl models, as well as centralisation and concentration, including the various ways in which compaction can be achieved including intensification, new high-density development, traditional neighbourhood development, etc. (Syrbe & Grunewald, 2017). Creating a balance between urban development, land take containment, climate adaptation and availability of Urban Green Areas and their related benefits is a challenge that impacts on the quality of the lives of the inhabitants, the economic performance of the city and the social justice and cohesion aspects (Kabisch & Haase, 2014). Better understanding cities as complex adaptive Socio-Ecological System and framing the role of Ecosystem Services within such system would largely support present and future sustainability and resilience of urban areas (Hansen et al., 2015; Schewenius, McPhearson, & Elmqvist, 2014).

1.1 PROBLEMS STATEMENT, RESEARCH QUESTIONS AND OBJECTIVES

While cities in Europe host around 60% of the total population, urban areas will face a diverse range of challenges in the following years (Alberti et al., 2019). Greening the city to support transition towards urban sustainability and resilience has been lately considered one of the most interesting transversal solutions to numerous urban challenges (Almenar et al., 2021).

A better integration of nature related concepts (ES, GBI and NBS) from top-down initiatives, strategies, and directives at European or International level would largely contribute to boost the transition towards sustainable and resilient cities. Thus, the first objective of this study would be to better understand to what extent current international and European policies are relevant for and recognized the role of nature and cities, which gaps currently exist and how they can be addressed. Through the review of current International (Chapter 2) and European (Chapter 3) policies, strategies, and agreement potentially relevant for nature and cities' role toward sustainability, we will look for references to the ES framework or to GBI and NBS and develop recommendation for a further integration of such concepts into relevant normative framework.

Nevertheless, while the concept of greening the city is currently spreading in the scientific and in the public discourse, it is not fully clear what introducing nature in the city means. The main concepts that have been used for describing and designing urban green areas and the most relevant issues for sustainable urban planning have not been deeply explored. Clarifying those concepts would then be the second specific objective of this work that will be presented in Chapter 4 where the most relevant concept for planning (Ecosystem Services ES, Green and Blue Infrastructure GBI and Nature-Based Solutions NBS) will be deeply presented.

Whether there is a common understanding on the fact that the transition from traditional urban planning to an ecosystem-based planning approach could support cities in achieving desired sustainability and resilience (Elmqvist et al., 2019; European Commission, 2019; Rozas-Vásquez, Fürst, Geneletti, & Almendra, 2018; Vasishth, 2008; Woodruff & BenDor, 2016), this new approach is still far from being systematically integrated into cities' plans and strategies. The operationalisation of an ecosystem-services based approach into urban planning and policies seems slow and problematical, therefore this work aims at providing a comprehensive ecosystem service-based planning approach for local authorities towards urban sustainability and resilience. After a systematization of the terminology and concepts, Chapter 4 builds on the ES cascade model (Potschin & Haines-Young, 2011) to highlight the socio-ecological relationships between ecosystem structures (ES supply), services and the benefits (ES flow) that people (ES demand) gain from ecosystems in urban areas. The proposed approach looks at the benefits of greening as a powerful driver of sustainability in terms of environmental and climate related challenges (Regulating Ecosystem Services) and as a powerful driver of quality of life (Cultural Ecosystem Services).

Studies over the mapping and assessment of the total urban supply of Ecosystem Services (ES) by local GBI are raising (Nowak, Crane, & Stevens, 2006; Paracchini et al., 2014; Peña, Casado-Arzuaga, & Onaindia, 2015; Wolch, Byrne, & Newell, 2014; Zardo, Geneletti, Pérez-Soba, & Van Eupen, 2017) and they define methods and tools to support cities in better understanding the current distribution of ES within the city. Nevertheless, assessing and evaluating not only ES supply or potential supply but also related quality and distribution of the existing GBI, would largely raise awareness on people needs in terms of open green spaces and could support planners and decision makers when making decisions on urban densification and/or regeneration processes. Also, practices and studies on ES diversified demand, citizens' perception and co-production are lacking (Andersson, 2020, Langemeyer, 2020) and the scale of application is harmed on one hand by the availability, the quality, the type and the usability of available data and on the other hand by the difficulties in considering the different socio-ecological dimensions of the problem. Being able to better assess ES supply and demand, both in terms of RES and CES, and to foster the understanding of the distribution of benefits in urban areas would largely support urban planners and decision makers in taking decision over land use priorities and regeneration opportunities; answering to this research question would then be one of the main ambitions and objectives of this dissertation.

In this direction, Chapter 5 will present methods to evaluate the benefits of greening as a powerful driver of sustainability in terms of environmental and climate related challenges (Regulating Ecosystem Services) through the case study application around three Regulating Ecosystem Services in the city of Bologna (run-off control, PM10 filtering and carbon sequestration) and Chapter 6 will focus on Cultural Ecosystem Services as crucial drivers of quality of life developing on physical recreation, cognitive and educational development, cultural recreation and social cohesion aspects. Distributional justice aspects will be also discussed in relation with CEs distribution over the city of Bologna.

Last, planning approach should not just look at the current situation, but it should aim at ensuring Ecosystem Services resilience over the time, including both RES and CES. This process implies that planning should continuously deal with uncertainties and that urban policies should be adaptive – devised not to be optimal for a best estimate future, but robust across a range of plausible futures (Walker, Holling, Carpenter, & Kinzig, n.d.)- in the light of diverse and changing demands for ES benefits in the future. However, from a practical perspective, while mathematical modelling and machine learning approach can support predictions of plausible future, build resilience building resilience around urban SES is far from obvious. The goal of Chapter 7 is therefore to present the development and the application of a participatory approach, building on the seven ES principle for resilience (Biggs et al., 2012) and the three ENABLE filters (Andersson et al., 2019), to better inform planning processes and policies on the crucial role of ecosystem services resilience for urban sustainable transition.

1.2 RESEARCH APPROACH AND METHODOLOGY

The general approach of this research combines the review of the current state of environmental policies (Chapter 2 and Chapter 3), scientific literature of interdisciplinary fields, mainly urban planning, urban ecology, urban geography and ecology with the development of new conceptual and methodological approach (Chapter 4). The proposed conceptual and methodological approach has then been tested in 2 case studies, in the city of Bologna and Barcelona, with a practical application and evaluation. A multi-method approach to data collection is used, applying to the case study of the city of Bologna (Chapter 5 and Chapter 6) both qualitative research methods, such as content analysis on policy documents, quantitative research methods, such as GIS spatial analysis, descriptive and spatial statistics, and computational software (I-tree). The conceptual and methodological approach also includes the development of a participatory and transdisciplinary approach that has been tested in a stakeholders' workshop in Barcelona (Chapter 7).

1.3 POLICY, SCIENTIFIC AND SOCIETAL RELEVANCE

The relevance of this dissertation, due to the intrinsic multidisciplinary and transdisciplinary needed approach of the topic, touches upon three different level:

1. **Scientific contribution around Cultural Ecosystem Services assessment and resilience of ES**

The present work can play a role in advancing scientific knowledge on: i) CES co-production and Urban Green Areas quality assessment (Fischer & Eastwood, 2016; Kabisch, van den Bosch, & Lafortezza, 2017; Quatrini et al., 2019) ii) the topic of just access and distribution of Cultural Ecosystem Services in urban areas (Rutt & Gulsrud, 2016) iii) the concept of ES resilience through the tailoring of the seven principle of Ecosystem Services resilience (Biggs et al., 2012) to the urban realm through the development of a dedicated Matrix.

2. Policy and planning development and innovation

The conceptual and methodological approach to map, assess and determine future resilience of ES and the relative methods and tools can strongly support the transition towards ecosystem services-based planning and decision making. The developed indicators and the consequent methods to map, assess and monitor those within the urban environment will allow local authorities to identify priority areas in the city, providing valuable contribution to the dilemma of sustainable compactness (Hansen, Olafsson, van der Jagt, Rall, & Pauleit, 2019; Peschardt, Schipperijn, & Stigsdotter, 2012). Also, through the development of the participatory methods to foster resilience of ES, issues in inter-sectorial collaboration (i.e greening, health, planning, mobility and tourism department) can be overcome.

3. Societal impact in terms of sustainable, resilient, and just urban transition

This dissertation builds on the idea of the city as complex adaptive Socio-Ecological System, where the ecological and the socio-economic structure continuously and dynamically interact (Geijzendorffer et al., 2017). The idea of ES as one of the possible indicators to monitor such interactions, as further developed and proposed throughout the work, could support cities in facing current societal challenges. Through the acknowledgment of SDG11, the role of cities as driver of sustainable urbanization is now clearly recognized at international level (Wendling, Huovila, zu Castell-Rüdenhausen, Hukkalainen, & Airaksinen, 2018), and within this work, we believe that this could be enhanced through the application of an ecosystem services- based planning approach. Analysing the ecological component (ES supply), the social component (ES demand) and the possible mismatches between the two, our aim is to support cities in both enhancing their path towards the ecological transition, and also in acting towards a just transition, including the population needs (ES demand) and relevant vulnerabilities in the plan for future sustainable and resilient cities.

LIST OF REFERENCES

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, *125*, 254–259. https://doi.org/10.1016/j.landurbplan.2014.01.020

Alberti, V., Alonso Raposo, M., Attardo, C., Auteri, D., Ribeiro Barranco, R., Batista E Silva, F., … Zulian, G. (2019). *The Future of Cities: Opportunities, challenges and the way forward*. https://doi.org/10.2760/375209

Almenar, J. B., Elliot, T., Rugani, B., Philippe, B., Gutierrez, T. N., Sonnemann, G., & Geneletti, D. (2021). Nexus between nature-based solutions, ecosystem services and urban challenges. *Land Use Policy*, *100*.

Andersson, E., Langemeyer, J., Borgström, S., McPhearson, T., Haase, D., Kronenberg, J., … Baró, F. (2019). Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems. *BioScience*, *69*(7), 566–574. https://doi.org/10.1093/biosci/biz058

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S. B., Cundill, G., … West, P. (2012). Toward Principles for Enhancing the Resilience of Ecosystem Services. *Ssrn*. https://doi.org/10.1146/annurev-environ-051211-123836

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., … van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*, 253–260.

Crutzen, P. J. (2002). Geology of mankind. *Nature*, *415*(6867), 23. https://doi.org/10.1038/415023a

Dearing, J. A., Wang, R., Zhang, K., Dyke, J. G., Haberl, H., Hossain, M. S., … Poppy, G. M. (2014). Safe and just operating spaces for regional social-ecological systems. *Global Environmental Change*, *28*(1), 227–238. https://doi.org/10.1016/j.gloenvcha.2014.06.012

Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., … Le Roux, X. (2015). Nature-based solutions: New influence for environmental management and research in Europe. *Gaia*, *24*(4), 243–248. https://doi.org/10.14512/gaia.24.4.9

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., … Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability*, *2*(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Ernstson, H. (2013). The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes. *Landscape and Urban Planning*, *109*(1), 7–17. https://doi.org/10.1016/j.landurbplan.2012.10.005

European Commission. (2019). *EU guidance on integrating ecosystems and their services into decision-making*. 64.

Fischer, A., & Eastwood, A. (2016). Coproduction of ecosystem services as human-nature interactions - An analytical framework. *Land Use Policy*, *52*, 41–50.

Frank, B. (2017). Urban Systems: A Socio-Ecological System Perspective. *Sociology International Journal*, *1*(1). https://doi.org/10.15406/sij.2017.01.00001

Gascon, M., Mas, M. T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. *International Journal of Environmental Research and Public Health*, *12*(4), 4354–4379. https://doi.org/10.3390/ijerph120404354

Geijzendorffer, I. R., Cohen-Shacham, E., Cord, A. F., Cramer, W., Guerra, C., & Martín-López, B. (2017). Ecosystem services in global sustainability policies. *Environmental Science and Policy*, *74*(January), 40–48. https://doi.org/10.1016/j.envsci.2017.04.017

Geijzendorffer, I. R., Martín-López, B., & Roche, P. K. (2015). Improving the identification of mismatches in ecosystem services assessments. *Ecological Indicators*, *52*, 320–331.

https://doi.org/10.1016/j.ecolind.2014.12.016
Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019
Güneralp, B., Zhou, Y., Ürge-Vorsatz, D., Gupta, M., Yu, S., Patel, P. L., … Seto, K. C. (2017). Global scenarios of urban density and its impacts on building energy use through 2050. *Proceedings of the National Academy of Sciences of the United States of America*, *114*(34), 8945–8950. https://doi.org/10.1073/pnas.1606035114
Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., … Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, *43*(4), 413–433. https://doi.org/10.1007/s13280-014-0504-0
Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., … Pauleit, S. (2015). The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosystem Services*, *12*, 228–246. https://doi.org/10.1016/j.ecoser.2014.11.013
Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E., & Pauleit, S. (2019). Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators*, *96*(November 2016), 99–110. https://doi.org/10.1016/j.ecolind.2017.09.042
Hoornweg, D., Hosseini, M., Kennedy, C., & Behdadi, A. (2016). An urban approach to planetary boundaries. *Ambio*, Vol. 45, pp. 567–580. https://doi.org/10.1007/s13280-016-0764-y
IPBES. (2016). *Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform. S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L.A. Acosta, H. R. Akçakaya, L. Br*.
IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *IPCC, Geneva, Switzerland, 151 Pp.* https://doi.org/10.1016/S0022-0248(00)00575-3
Kabisch, N., & Haase, D. (2014). Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and Urban Planning*, *122*, 129–139. https://doi.org/10.1016/J.LANDURBPLAN.2013.11.016
Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review. *Environmental Research*, *159*(August), 362–373. https://doi.org/10.1016/j.envres.2017.08.004
Lampert, A. (2019). Over-exploitation of natural resources is followed by inevitable declines in economic growth and discount rate. *Nature Communications*, *10*(1), 1–10. https://doi.org/10.1038/s41467-019-09246-2
Langemeyer, J., Gómez-Baggethun, E., Haase, D., Scheuer, S., & Elmqvist, T. (2016). Bridging the gap between ecosystem service assessments and land-use planning through Multi-Criteria Decision Analysis (MCDA). *Environmental Science & Policy*, *62*, 45–56. https://doi.org/10.1016/j.envsci.2016.02.013
Lenton, T. M., Held, H., Kriegler, E., Hall, J. W., Lucht, W., Rahmstorf, S., & Schellnhuber, H. J. (2008). Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences*, *105*(6), 1786–1793.
McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., … Qureshi, S. (2016). Advancing Urban Ecology toward a Science of Cities. *BioScience*, *66*(3), 198–212. https://doi.org/10.1093/biosci/biw002
Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*, *4*(3–4), 115–123.

https://doi.org/10.1016/J.UFUG.2006.01.007
Paracchini, M. L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J. P., Termansen, M., … Bidoglio, G. (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. *Ecological Indicators*, *45*(2014), 371–385. https://doi.org/10.1016/j.ecolind.2014.04.018
Peña, L., Casado-Arzuaga, I., & Onaindia, M. (2015). Mapping recreation supply and demand using an ecological and a social evaluation approach. *Ecosystem Services*, *13*, 108–118. https://doi.org/10.1016/j.ecoser.2014.12.008
Peschardt, K. K., Schipperijn, J., & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). *Urban Forestry and Urban Greening*, *11*(3), 235–244. https://doi.org/10.1016/j.ufug.2012.04.002
Potschin, M. B., & Haines-Young, R. H. (2011). Ecosystem services: Exploring a geographical perspective. *Progress in Physical Geography*, *35*(5), 575–594. https://doi.org/10.1177/0309133311423172
Quatrini, V., Tomao, A., Corona, P., Ferrari, B., Masini, E., & Agrimi, M. (2019). Is new always better than old? Accessibility and usability of the urban green areas of the municipality of Rome. *Urban Forestry and Urban Greening*, *37*(July 2017), 126–134. https://doi.org/10.1016/j.ufug.2018.07.015
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., … Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2). https://doi.org/10.5751/ES-03180-140232
Romero-Lankao, P., Gnatz, D. M., Wilhelmi, O., & Hayden, M. (2016). Urban sustainability and resilience: From theory to practice. *Sustainability (Switzerland)*. https://doi.org/10.3390/su8121224
Rozas-Vásquez, D., Fürst, C., Geneletti, D., & Almendra, O. (2018). Integration of ecosystem services in strategic environmental assessment across spatial planning scales. *Land Use Policy*, *71*, 303–310. https://doi.org/10.1016/j.landusepol.2017.12.015
Rutt, R. L., & Gulsrud, N. M. (2016). Green justice in the city: A new agenda for urban green space research in Europe. *Urban Forestry & Urban Greening*, *19*, 123–127. https://doi.org/10.1016/J.UFUG.2016.07.004
Schewenius, M., McPhearson, T., & Elmqvist, T. (2014). Opportunities for increasing resilience and sustainability of urban social-ecological systems: Insights from the URBES and the cities and biodiversity outlook projects. *Ambio*. https://doi.org/10.1007/s13280-014-0505-z
Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., … Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences of the United States of America*, 201810141. https://doi.org/10.1073/pnas.1810141115
Syrbe, R. U., & Grunewald, K. (2017). Ecosystem service supply and demand–the challenge to balance spatial mismatches. *International Journal of Biodiversity Science, Ecosystem Services and Management*, *13*(2), 148–161. https://doi.org/10.1080/21513732.2017.1407362
UN. (2016). *New urban agenda - Habitat III*.
UN. (2018). *World Urbanization Prospects The 2018 Revision*.
UNCBD. (2020). Global Biodiversity Outlook. In *Secretariat of the Convention on Biological Diversity* (Vol. 25).
Vasishth, A. (2008). A scale-hierarchic ecosystem approach to integrative ecological planning. *Progress in Planning*, *70*(3), 99–132. https://doi.org/10.1016/j.progress.2008.05.001
Verma, P., & Raghubanshi, A. S. (2018). Urban sustainability indicators: Challenges and opportunities. *Ecological Indicators*, *93*(February), 282–291.

https://doi.org/10.1016/j.ecolind.2018.05.007
Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (n.d.). *Resilience, Adaptability and Transformability in Social– ecological Systems*.

Wendling, L. A., Huovila, A., zu Castell-Rüdenhausen, M., Hukkalainen, M., & Airaksinen, M. (2018). Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework. *Frontiers in Environmental Science*, *6*(JUL), 1–18. https://doi.org/10.3389/fenvs.2018.00069

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough.' *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/J.LANDURBPLAN.2014.01.017

Woodruff, S. C., & BenDor, T. K. (2016). Ecosystem services in urban planning: Comparative paradigms and guidelines for high quality plans. *Landscape and Urban Planning*, *152*, 90–100. https://doi.org/10.1016/j.landurbplan.2016.04.003

Zardo, L., Geneletti, D., Pérez-Soba, M., & Van Eupen, M. (2017). Estimating the cooling capacity of green infrastructures to support urban planning. *Ecosystem Services*, *26*, 225–235. https://doi.org/10.1016/j.ecoser.2017.06.016

2 THE RECOGNITION OF NATURE AND CITIES' ROLE INTO THE CURRENT INTERNATIONAL CONTEXT

ABSTRACT

While international cooperation relies on negotiations and coordination among Countries, the achievement of global sustainable development targets and goals will also be determined by cities as they largely drive cultures, economies, material use, and waste generation. Nevertheless, the need of urban responses, in terms of local sustainable and resilient policies and strategies, and the role of biodiversity and nature as crucial drivers of sustainable transition, have not been clearly stated at international level until the United Nations Conference on Environment and Development (UNCED) that took place in Rio de Janeiro 1992. Since then, the role of cities and sustainable planning in determining local and global sustainable development started to increase at international level leading to the development of a dedicated goal within the UN Sustainable Development Goals (N.11) and the New Urban Agenda. This chapter aims at providing an overview of the role of natural and urban environment in securing sustainable and inclusive urban sustainability towards current challenges in selected relevant international strategies and agreements. In the context of this study, the protection of biodiversity at a global level, the path to fight against climate change and the recognition of the crucial role of cities into the path towards a sustainable development are explored. Specifically, looking at natural and urban environment as crucial actors toward a sustainable urban transition, this chapter will investigate the integration of these two concepts within the identified milestones at international level.

2.1 THE INTERNATIONAL CONTEXT BEFORE 1992

Despite short-term downturns and setbacks, constant economic growth over the last 200 years has generally resulted in raising standards of living and improving quality of life , highlighting disparities among the global North and South (Bader, Bieri, Wiesmann, & Heinimann, 2017) and at the same time producing depletion of natural resources, degradation of ecosystems (Millenium Ecosystem Assessent, 2005) and change in the atmosphere that are causing climate change and fluctuation . Natural resources are at the same time vital for securing economic growth and development for today and for future generations and are posed at risk by the same economic system they support (Everett, Ishwaran, Ansaloni, & Rubin, 2010). The impact of humans on earth ecosystems has a long history and scientists place the start of the so-called Anthropocene (Crutzen, 2002) from the second half of nineteenth century. Anthropocene has been defined as the period in which human activity dominates the development of global ecosystems (Sterner et al., 2019) and introduces the idea that human species has become a geological force in terms of its capacity for affecting Earth's processes (Kavalski & Zolkos, 2016). The Anthropocene start has been placed at the beginning of the 18th century, when analyses of air trapped in polar ice showed growing global concentrations of carbon dioxide and methane in the atmosphere. The Anthropocene is a potentially revolutionary concept since it implies the need to evaluate how we understand human social actions and its consequences and impact on Earth (Bauer & Ellis, 2018). The Anthropocene idea highlights the concrete impact of humans on the actual geological and geomorphological features of the planets, underlying its limit in carrying capacity and recalling the concepts of defined planetary boundaries (Rockström et al., 2009; Steffen et al., 2018) and tipping points (Lenton & Williams, 2013). Indeed, the impact of humans on planet earth is heavily affecting the earth ecosystems, simultaneously pushing it to overcome its natural carrying capacity in terms of resources (Wisniewski, 1980; del Monte-Luna *et al.*, 2004), depleting the quality and the functions of the same ecosystems and affecting its natural cycle and functioning.

At the beginning of the XX century, environmental concerns started to raise among science, politics and the civil society. The Trail Smelter dispute (1941) was a trans-boundary pollution case involving the federal governments of both Canada and the United States, which eventually contributed to establishing the harm principle in the environmental law of transboundary pollution. Among other references, the book Silent Spring (Carson, 1962), raised great attention and controversy at the time. The book focused on the extended use of pesticide in agriculture and on the potential impacts that this could have on nature and humans' health. The raise of the ecologist movement contributed to push international actors such as the United Nations to start thinking about healthy and just human environment. Global policymaking, which is especially important for those planetary boundaries linked to global pollutants, such as climate change, ocean acidification and novel entities (Rockström et al., 2009), must be forged despite the broad absence of governance structures powerful enough to enforce regulations or taxes to ensure sustainable global development (Sterner et al., 2019). Fig 2-1 summarizes the most important milestones in international agreement that will be further developed in the following sections.

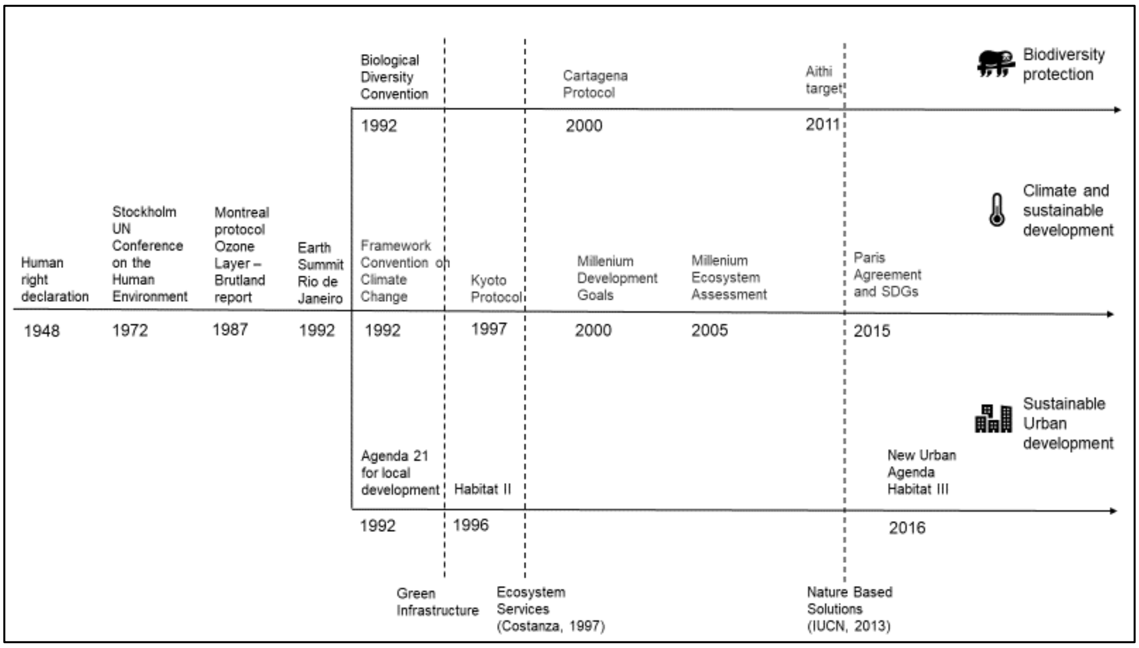


Figure 2-1 Milestones in international agreement from 1948 to present day (Author elaboration)

The Universal declaration on human right, signed in New York in December 1948 (United Nations, 1948) and followed by the International Covenant on Economic, Social and Cultural Right firstly recognized the right of every human to constantly seek for better living conditions and enjoyment of the highest reachable physical and mental health. Art 11 in particular "*recognize the right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions. The States Parties will take appropriate steps to ensure the realization of this right, recognizing to this effect the essential importance of international cooperation based on free consent*, while Art 12 highlights and states *the right of everyone to the enjoyment of the highest attainable standard of physical and mental health*. This includes the constant seek for "*improvement of all aspects of environmental and industrial hygiene*". Nevertheless, despite the clear recognition of two fundamental human rights such as the right of adequate standard and healthy status, none of these documents clearly mention nor define the link of these rights with the natural environment conditions as a crucial precondition for health and life right. The path towards international agreements and strategies to push towards a more sustainable model of development recognizing nature and natural environment as fundamental actors in securing such rights, started in Stockholm in 1972.

2.1.1 STOCKHOLM UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT 1972

The recognition of the role of nature, ecosystem and more generally the environment into humans' life was firstly stated during the Stockholm United Nations Conference on the Human Environment (United Nations, 1972) that first mention the concept of sustainable development and recognize the need of an international approach towards the environmental issue. This conference is considered a milestone into environmental policies definition and further development since it embedded global awareness around environmental issues and officially brought such issues into international institutions. The conference adopted the Declaration of United Nations Conference on the Human Environment that is made by 26 general principles an action plan for the environment. Among those principles, Principle 2 defines enounced that '*natural resources on earth including the air, water, land flora and fauna and especially representative samples of natural ecosystems must be safeguarded for the benefit of the present and future generations through careful planning and management as appropriate*' developing on the idea of limited resources and relative benefits that need careful planning and management to be maintained and secured for future generations. Also, during this conference members of the United nations constitute the **United Nation Programme on Environment (UNEP)** as a dedicated agency to work on environmental concerns.

2.1.2 MONTREAL PROTOCOL TO PROTECT THE OZONE LAYER (1987)

Even though there is no specific role of cities or nature recognized in Montreal Protocol (United Nations 1987), this example is particularly relevant and it has been included as a milestone in the path towards agreed actions on environmental issues since it represents a success story of international cooperation (Strahan & Douglass, 2018). From the '60s, rapid changes in human behaviour caused a significant demand for Chlorofluorocarbons (CFCs) and in rapid depletion of ozone. The atmospheric iodine levels in the North Atlantic, a proxy for ozone depletion, tripled from 1950 to 2010 (Cuevas et al., 2018). Simulations by Newman et al. 2009 indicated that in a world without the Montreal Protocol and manufacturing grew at an annual rate of 3%, a complete lower-stratospheric ozone loss would have occurred by 2058. There is solid evidence that deliberate intergovernmental action has reversed ozone depletion. International cooperation and agreements in this area contributed to reach the agreed targets and avoid ensuing risk of a cascade of catastrophic changes in socio-environmental systems following the collapse of stratospheric ozone. The ozone layer showed signs of recovery after atmospheric chlorine levels peaked around 1993 and steadily declined afterwards (Strahan & Douglass, 2018). The World Meteorological Organization (WMO, 2019) predicts that full compliance with the Montreal Protocol will result in stratospheric ozone levels returning to the 1960 benchmark after 2050 in most latitudes and by the end of the 21st century for Antarctic ozone.

It could be argued that the CFCs controls and regulation represent a linear and single scale issue, not comparable in terms of complexity with global climate change relations and consequences, and this is partly true. Nevertheless, this suggests that international agreements on environmental issues can reach the foreseen target, whether those are clearly and explicitly set and agreed, and all the parties collaborate towards those.

2.1.3 BRUNDTLAND REPORT (1987)

Because of the low impacts on world development and on environmental degradation of the 1972 Stockholm UN Conference on the Human Environment and successive reports, the World Commission on Environment and Development (WCED) was established and presented its report, also known as the Brundtland Report in recognition of former Norwegian Prime Minister Gro Harlem Brundtland's role as Chair, at a press conference in London on 27th April 1987 (World Commission on Environment and Development,WCED, 1987).

This report was the outcome of an intense, 900 days long international work that, through a continuous consultation with several experts (government bodies, NGOs, scientific community). Scientists brought to the WCED attention *urgent but complex problems bearing on our very survival: a warming globe, threats to the Earth's ozone layer, deserts consuming agricultural land*. The report, therefore, focused on hunger, poverty and underdevelopment, but also, on overdevelopment that was causing main challenges to environment and ecosystems' functioning and health. Also, the report adopted one of the fundamental tenets of the Green movement, that of sustainable development:

"*Sustainable development is development that meets the needs and aspirations of the present generation without destroying the resources needed for future generations to meet their needs. It contains two key concepts: firstly, the idea of meeting needs, and in particular the needs of the world's poor, through more equitable distribution of* *opportunities and resources; secondly, the concept of limitations of growth and of resource depletion imposed by the ability of the environment to meet future needs*" (WCED, 1987).

The statement that the *environment does not exist as a sphere separate from human actions, ambitions, and needs,* eventually recognized environment and development as one single issue and placed environmental issues firmly at the top of the international political agenda. The report recognized, among others, two priorities particularly relevant in the context of this work: species and ecosystems and the urban challenge. Specifically, concerning species and ecosystem, the report states that '*conservation of living natural resources - plants, animals, and micro-organisms, and the non-living elements of the environment on which they depend - is crucial for development.* Even though the ecosystem services framework was not recognized at the time as such, the Brundtland report recognized that *equally important are the vital life processes carried out by nature, including stabilization of climate* (microclimate regulation), *protection of watersheds and soil* (water management and soil protection)*, preservation of nurseries and breeding grounds* (genetic diversity)*, and so on. Conserving these processes cannot be divorced from conserving the individual species within natural ecosystems.* Being population growth and future needs central in the document, the report not only included the conservation of the ecosystem services as such, but also acknowledged *the growing pressures of future high demands for both goods and services that depend upon these natural resources*.

Although recognizing that *aesthetic, ethical, cultural, and scientific considerations provide ample grounds for conservation* themself, the report mostly focus on the economic value of such resources, including agriculture (food production), genetic and pharmaceutical value. Last, it recommends national government to set up National Conservation Strategies (NCS), that would bring the processes of conservation and development together *involving government agencies, non-governmental organizations, private interests, and the community at large in analysis of natural resource issues and assessment of priority actions.* The role of local governments and communities also raised in the recognition of another crucial challenge treated in the report: the urban challenge. Poverty, rural-urban migration and consequent overpopulation and pollution are the main issues considered in this chapter. Planning, informal use of land and local authorities and communities' role are also mentioned. The role of urban planning in land-use decision and the recognition of the difficulties in re-designing previous choices (as urban regeneration actions) are clearly mentioned in the document. Particularly interesting is the direct reference to land use and urban green spaces '*haphazard development also consumes land and natural landscapes needed for urban parks and recreation areas. Once an area is built up, it is both difficult and expensive* *to re-create open space'*. Also, the multifunctional values of urban green areas, and the potential co-benefits of such spaces is already acknowledged, especially with regards of urban farming and agriculture that '*could become an important component of urban development and make more food available to the urban poor* (food production and social justice and cohesion). *The primary purposes of such promotion should be to improve the nutritional and health standards of the poor* -social and environmental value- *help their family budgets (...) enable them to earn some additional income and provide* ***employment*** - economic value. *Urban agriculture can also provide fresher and cheaper produce, more green space, the clearing of garbage dumps, and recycling of household waste* -waste regulation.

In line with the proposal for a National Conservation Strategies, the report proposed national governments to set up a National Urban Strategy that *could provide an explicit set of goals and priorities for the development of a nation's urban system and the large, intermediate, and small centres within it*. The Strategy started to strengthen local authorities' role and boost participation and citizens involvement, paving the way for the Agenda 21 that was then further developed in 1992.

2.1.4 SUSTAINABLE DEVELOPMENT UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT, RIO DE JANEIRO, 1992

The United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992 and known as the Earth Summit, was the international diplomatic response to the challenges expressed in the Brundtland report. Indeed, at the Earth Summit world's political leader acknowledged the need of a united political response towards sustainable development and committed and paved the way towards a series of nominally binding agreements on climate and biodiversity (Jordan & Voisey, 1998). The Earth Summit delivered four main products: i) the Rio Declaration on Environment and Development ii) the Convention of Biological Diversity iii) the United Nations Framework Convention on Climate Change iv) the Agenda 21.

Building on these products, the following paragraphs develop on climate and sustainable development agreements (3.3), biodiversity conventions and protocol (3.4) and urban cooperation and local authorities (3.5) from 1992 up to the present day, highlighting the role of nature and ecosystem services in these 3 diverse international paths.

2.2 CLIMATE AGREEMENTS FROM 1992

The World Climate Conference, where the potential issues of raising climate change have firstly been discussed internationally, took place in Geneva in 1979 (World climate conference, 1979) and initiated the international debate on climate change and global warming as summarized in Table 2-1.

Table 2-1 Timeline of the main Climate International agreements from 1979 to 2020 (Author elaboration based on Gupta, 2010)

Period	The Paradigm	Key dates and Outcomes
Before 1991	Framing the problem	1979: First World Climate Conference 1988: Establishment of IPCC; First UN General Assembly; Resolution on climate change
1992–1996	Road to Kyoto	1992: Climate Change Convention 1995: COP-1—Berlin Mandate 1996: Second Assessment Report of IPCC
1997–2014	From Kyoto to Paris	COP-3—The Kyoto Protocol 2000: Third Assessment Report of IPCC 2001: United States withdraws from Kyoto 2005: Kyoto enters into force 2009: COP-15—Copenhagen Accord
2015- 2020	From Paris up to present day	2015 Paris Agreement 2016 Paris agreement entered into force 2017 US withdraw from Paris Agreement 2019 Madrid COP 25

As described in the previous paragraph, the Brundtland report placed climate change among the most warning global issues together with pollution, use of limited natural resources and inequality among rich and poor countries. The United Framework convention on Climate Change (United Nations, 1992d) represents the first international attempt to pave the way towards a global action against climate change. In its preamble the UN expressed their concerns about the steadily increase of Greenhouse Gases (GHG) in previous decades and feared that '*this will result on average in an additional warming of the Earth's surface and atmosphere and may adversely affect natural ecosystems and humankind*'. The link *of* strong and resilient ecosystems and their productivity - services they produce - with human health and welfare is already stated in the preamble that recognised the '*role and importance in terrestrial and marine ecosystems of sinks and reservoirs of greenhouse gases*' and the potential deleterious effect of climate change on the '*composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare*'. Nevertheless, the recognition of natural ecosystems and socio-economic systems as a unique concept of socio-ecological system is not acknowledged yet, but the two are rather considered as separate entities, affecting each other but still treated as independent components of the system.

Art. 2 develops the main objective of the Convention that claims for '*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system and [...] within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner*'. The objective of the Climate Convention directly mentions climate regulation and food production as crucial provisioning and regulating ecosystem services and clearly recognizes the link among healthy and functioning ecosystem services and sustainable economic development. Ecosystems and nature are recognized as a vital element that should be preserved to maintain human welfare and wellbeing. Ecosystems and their services are recognized as essential for human life, and they should be protected and conserved. Nevertheless, they are not considered themselves as potential solutions to societal challenges towards sustainable development – as later with the introduction of the nature-based solutions concept (Raymond et al., 2017) – neither for their symbolic, and non-material, cultural and ecological values (Kavalski & Zolkos, 2016).

At organizational level, the Convention went much further than previous agreements and established a comprehensive organizational framework setting up the full-time secretariat of the Conference of Parties (COP) and establishing that such a conference should meet annually to decide on key issues, revising targets and financial supporting schemes. The establishment of the COP mechanism brought to the adoption of the Kyoto Protocol in 1997 during the COP3 (UNFCCC, 1997). The protocol did not include new targets or objectives, but rather worked on methods, policies and measures that countries can adopt to reach the Climate Convention targets (Gupta, 2010). The protocol focuses on reducing GHG emissions, mostly in relation with energy efficiency and transport measures, but also included measures regarding conservation of ecosystems and their services, generally referring to enhancement of sinks and reservoirs, sustainable forest management and sustainable agriculture. The Kyoto protocol was adopted in 1997, but it encompassed a long path with the US withdrawing it in 2001 and Russia and Japan ratifying it the Protocol in 2005 before entering into force. The fifth report of the IPCC (IPCC, 2014) on the impact of climate change on the earth, the raising public awareness of climate justice and environmental issues, the complexity of the Kyoto Protocol's flexibility mechanisms and its tendency to encourage self-serving negotiating strategies (Gupta, 2010; Soroos, 2001) and the raising emissions of the main GHGs (carbon dioxide, methane and nitrous oxide), raised questions about the functioning of such an instrument and created large public expectations concerning the 2009 COP-15 in Copenhagen. Unfortunately, such expectations were not met by the Copenhagen agreement where Parties could not agree on many of the issues at the table. Many observers, at the time, regretted that international climate diplomacy had reached a dead end in Copenhagen (Falkner, 2016). In this regard, it is worth to point out that the meeting in Copenhagen took place in a context of global economic recession. However, the Doha amendment in 2012 extended the life of the Kyoto Protocol until 2020 and Parties discussed that global efforts should limit the rise in the planet's average air temperature to no more than 2°C above pre-industrial levels (Falkner, 2016) starting the path towards a new global agreement to be agreed in Paris in December 2015 (Leal-Arcas & Carafa, 2014). At the same time, in those years the concept of ES, GBI and NBS entered the policy-making language in Europe and internationally (Eggermont et al., 2015; EU Commission, 2013; Millenium Ecosystem Assessent, 2005), and climate change effects became clear with increasingly common extreme climate events – raisings floods, heat wave, droughts- and long lasting changes – permafrost melt, ocean circulation, etc. – touching upon climate justice, planetary boundaries and uncertain tipping points evolution. The urgency of another more ambitious agreement was clearly on the table even before the Paris Agreement.

On 12th December 2015, the text of the Paris Agreement was approved as a pact containing all the elements necessary to build a global strategy for the fight against climate change for the post-2020 period (United Nations, 2015b). The rather ambiguous text was a compromise between the aspirations for a global legally binding treaty on the part of the EU, and the desire for legal flexibility on the part of the US, China and other emerging economies.

The biggest change from previous climate agreements regards the role and the primacy of domestic politics in climate change, allowing countries to set their own level of ambition for climate change mitigation. With respect to previous protocols and agreements, climate adaptation measures assumed a central relevance with clear indications to countries to *enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change […] following a country-driven, gender-responsive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems, and […] based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions, where appropriate.*

The reference to best available science, traditional knowledge and knowledge of indigenous people could be related to nature and ecosystem-based solutions, despite they are not mentioned as such in the agreement. Also, the agreement mentions the need of increasing '*resilience* of *communities, livelihoods and ecosystems'* and highlights *'the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity, recognized by some cultures as Mother Earth.* The agreements also recognized the link between the protection of communities, oceans and ecosystems *and [...] the importance of the concept of* "*climate justice*"*, when taking action to address climate change*'.

Within the Paris agreement, ecosystems, biodiversity and nature are considered, more than in previous climate agreement, vulnerable natural places to be preserved as such, linked with local traditions and heritage, but also with communities, vulnerabilities and justice. While the recognition of the role of forests and re-forestation as a crucial policy measure to increase global mitigation target was already acknowledged in previous agreements, the increasing significance of climate adaptation measures, rather than mitigation, could also boost the role of nature and ecosystems as appropriate policy measures to be implemented in national adaptation strategies.

Nevertheless, with the US withdraw formally started in November 2019, the failure of the last COP25 in Madrid and no clear pathway towards enhanced ambition of climate targets in 2020 (Streck, 2020), the 26th session of the Conference of the Parties (COP 26) to the UNFCCC will be a crucial step to re-define individual commitments and international cooperation methods. Originally scheduled to take place from 9-19 November 2020, in Glasgow, UK, due to the COVID-19 pandemic restrictions and uncertainty, this was postponed to 1-12 November 2021, in Glasgow, UK. At the moment, the main question would be whether the current pandemic will boost international cooperation and single country towards a broader understanding of the prevention principle in light of the impacts of the current pandemic or whether, on the opposite site, the attention on climate issues will be shifted for the following years overshadowed by current health and economic crisis.

2.3 SUSTAINABLE DEVELOPMENT AND BIODIVERSITY AGREEMENTS

Starting from the Earth Summit in 1992, and in parallel with the development of climate agreements, the United Nations also developed on the concept of international cooperation '*with the goal of establishing a new and equitable global partnership and [...] working towards international agreements which respect the interests of all and protect the integrity of the global environmental and developmental system'* (United Nations, 1992b) and around biodiversity goals and targets.

2.3.1 THE RIO DECLARATION AND THE CONVENTION ON BIOLOGICAL DIVERSITY

The first relevant document in this field is the 'Rio declaration on environment and development' that, in its preamble already *recognize the integral and interdependent nature of the Earth, our home*, and proclaims, in principle 1 that *human beings are at the centre of concerns for sustainable development and they are entitled to a healthy and productive life in harmony with nature,* reaffirming the declaration made in Stockholm in 1972. The Rio declaration doesn't mention any specific ecosystem services and remains a more general document of intentions. The main aim related with nature declares that '*states shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem*. At the same time, the Convention on Biological Diversity also opened for signature at the Rio Earth Summit in 1992 (United Nations, 1992a) . This Convention represents a dramatic step forward in '*the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources*'.

The recognition of natural environment as provider of the basic conditions '*for meeting the food, health and other needs of the growing world population*, without which humanity could not survive is clearly stated in the preface of the same convention as well as the need of guaranteeing just, fair and inclusive access to those benefits arising from genetic resources, biodiversity and ecosystems. The Convention encourages countries to *develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes and [...] to integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies*. The significance of integrating biodiversity and sustainable development issues in cross-sectoral policies is here clearly stated and will assume greater importance in the years to come. The convention also mentioned the need of introducing environmental impact assessment for those project or programme that could affect local biodiversity – as already in force in EU with the Environmental Impact Assessment (European Council, 1985) directive and the Strategic Environmental Assessment (EU parliament, 2001)– and defined that the Conference of the Parties should held regular annual meeting to monitor results and update targets of the convention. In this regard, as for the climate agreements, the Rio Declaration and the Convention on Biological diversity are crucial milestones in the path towards sustainable development and biodiversity conservation since it defined the main objectives to be reached, but it also established responsibilities and long-lasting cooperation process, i.e. the COP. Nevertheless, both documents did not aspire to set concrete and measurable goals and targets that, as in the case of the climate agreements, have been set some years later following a long negotiation process. Specifically, the following milestones in the advancement of an agreement towards international sustainable development and biodiversity conservation are the so-called Millennium Development Goals (MDGs) agreed at the United Nations Headquarters in New York, 2000, by 189 countries, and the Strategic Plan for Biodiversity, including the Aichi targets for the 2011-2020 period adopted a revised in Nagoya, Japan, in 2010 (UNEP, 2010).

2.3.2 THE MILLENNIUM DEVELOPMENT GOALS

The eight MDGs established in 2000 were: eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality, and empower women, reduce child mortality, improve maternal health, combat HIV, ensure environmental sustainability and develop a global partnership for development. Each goal was specified into 2 or 3 targets and relevant indicators, that have been used to monitor the overall progress towards the specific goal up to 2015.

Biodiversity, ecosystems, nature-based solutions and the services and the benefits they provide underpin all dimensions of human societal, cultural and economic wellbeing and even though not directly mentioned within the MDGs they could support and develop the way to achieve such goals. Specifically, at least two MDGs could have been directly impacted by a better use of nature-based solutions and further recognition of the ecosystem services' concept: eradicate hunger and ensure environmental sustainability. While nature-based solutions in terms of food production are not directly related to the specific targets developed for goal 1 – *eradicate extreme poverty and hunger* – the contribution of ecosystem services and NBS to *ensure environmental sustainability* is clear in all the targets of goal 7 and in most of its indicators as summarized in Table 2-2.

Table 2-2. MDG target indicators and the potential contribution of NBS and ES to their achievement. Author elaboration based on the Millennium Development Goals Report, 2015 (United Nations, 2015a)

Target	Indicators	Possibly related toto NBS and ES	Achievement up to 2015
Target 7A: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources	*7.1 Proportion of land area covered by forest*	Yes – reforestation and afforestation	An estimated 5.2 million hectares of forest were lost in 2010, an area about the size of Costa Rica.
	7.2 CO2 emissions, total, per capita and per $1 GDP (PPP)	Yes – trees planted	Global emissions of carbon dioxide have increased by over 50 per cent since 1990.
	7.3 Consumption of ozone-depleting substances	**No**	
	7.4 Proportion of fish stocks within safe biological limits	Yes – safe marine ecosystems or aquaculture	Overexploitation of marine fish stocks led to declines in the percentage of stocks within safe biological limits, down from 90 per cent in 1974 to 71 per cent in 2011.
	7.5 Proportion of total water resources used	Yes – natural water retention measures	Water scarcity affects 40 per cent of people in the world and is projected to increase.
Target 7.B: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss	*7.6 Proportion of terrestrial and marine areas protected*	Yes – ecosystem conservation and protection	Terrestrial and marine protected areas in many regions have increased substantially since 1990. In Latin America and the Caribbean, coverage of terrestrial protected areas rose from 8.8 per cent to 23.4 per cent between 1990 and 2014
	7.7 Proportion of species threatened with extinction	Yes – ecosystem conservation and protection	Species are declining overall in numbers and distribution.
Target 7.C: Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation	*7.8 Proportion of population using an improved drinking water source*	Yes - natural water retention measures	In 2015, 91 per cent of the global population is using an improved drinking water source, compared to 76 per cent in 1990. Of the 2.6 billion people who have gained access to improved drinking water since 1990, 1.9 billion gained access to piped drinking water on premises
	7.9 Proportion of population using an improved sanitation facility	**No**	
Target 7.D: By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers	*7.10 Proportion of urban population living in slums*	Yes	The proportion of urban population living in slums in the developing regions fell from approximately 39.4 per cent in 2000 to 29.7 per cent in 2014.

NBS and ES could be relevant for 7 out of ten specific indicators whose achievement are presented in the last column of the table. Unfortunately, it is not possible to understand the specific contribution of NBS and ES approach to such achievements, since this was not monitored as such, but the table clearly shows that even though some relevant targets have been achieved – increased in marine and terrestrial protected areas – some others are still far to be achieved and for those, further enhancement of NBS and ES would be necessary.

2.3.3 STRATEGIC PLAN FOR BIODIVERSITY, INCLUDING THE AICHI TARGETS, AND THE SUSTAINABLE DEVELOPMENT GOALS

While working on concrete actions to reach the Millennium development goals, the discourse on global sustainable development goals and biodiversity targets followed to prepare the ground to set new and more ambitious objectives for the future. The Rio20+ conference held in 2012 started the path to set in July 2014, the UN General Assembly Open Working Group (OWG) that proposed a document containing 17 goals to be put forward for the General Assembly's approval in September 2015, while the Strategic Plan for Biodiversity was discussed and approved in 2010. These documents set the ground for the development of the Sustainable Development Goals (SDGs) (United Nations, 2015c) agreed within the 2030 Agenda for sustainable development in New York from 25-27 September 2015 and for the development of the Aichi targets for biodiversity.

At that time, the interest and the knowledge around the ecosystem services framework and their integration into policies, strategies and local plans was raising in science and practice (Costanza et al., 2017; Cowling et al., 2008; Fisher et al., 2008; Nicholson et al., 2009). The discourse of ecosystem services and related benefits to human wellbeing and health is acknowledged throughout the Strategic Plan for biodiversity (UNEP, 2010), from the vision of *living in Harmony with Nature* where *by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people*.

ES and NBS are well stated in the plan that aims at *taking effective and urgent action to halt the loss of biodiversity in order to ensure that by 2020 ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life, and contributing to human well-being, and poverty eradication*. The Decision X/2 adopted by the COP explicitly mentioned 17 times ecosystem services in the plan, not just accrediting the need to ensure the continued and resilient provision of ecosystem services and their crucial role in human wellbeing, but also urging the need of advancing the scientific knowledge and the economic aspects of the topic. Out of this 17 mentions 2 explicit references are contained in the Aichi targets, specifically Target 11 on protection of terrestrial and marine ecosystems and their services, and Target 14 that established that *by 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable*.

The 17 SDGs cover from poverty and hunger reduction to responsible consumption and production; while MDGs just include one goal related with environmental and ecosystem issues, SDGs included at least six SDGs directly mentioning the topic – *SDG 6 Clean water and sanitation, SDG7 Affordable clean energy, SDG 12 responsible conception and production, SDG 13 Climate action, SDG 14 life below water, SDG15 Life on land* – and other 3 goals directly related with healthy ecosystems and nature based solutions – *SDG2 zero hunger, SDG3 good health and wellbeing, SDG 8 Decent work and economic growth, SDG9 Industry Innovation and infrastructure and SDG 11 Sustainable cities and communities.* To reach the ambitious targets defined in the SDGs, it will be necessary to manage ecosystems and to protect and enhance nature in built and natural environment. Also, it will be essential to enhance their resilience, maintaining their supply sustainable (Biggs, Schlüter, & Schoon, 2015) as well as the distribution of and the access to their benefits just and equitable (Wolch, Byrne, & Newell, 2014).

According to Geijzendorffer *et al.*, 2017, as showed in Fig.2-2, explicit references to single ecosystem service or implicit reference to the benefits of such services to human wellbeing are crossing at least 12 SDGs and 13 among the 20 Aichi targets, covering all the different ecosystem services categories. Specifically, in the SDGs provisioning services are mentioned 29 times, regulating services 33 times and cultural services 23 times, while in the Aichi targets we find 29 times provisioning services, regulating services 21 times and cultural services 13 times.

Interestingly, cultural ecosystem services are less represented in both policy documents, despite their crucial role in securing human health and wellbeing. Recent studies (Daniel et al., 2012; Geijzendorffer, Martín-López, & Roche, 2015) stake that more easily measurable services (i.e. regulating and provisioning services) with stronger methods and tools to assess and quantify their benefits, are then more easily translated into policy guide and strategic documents.

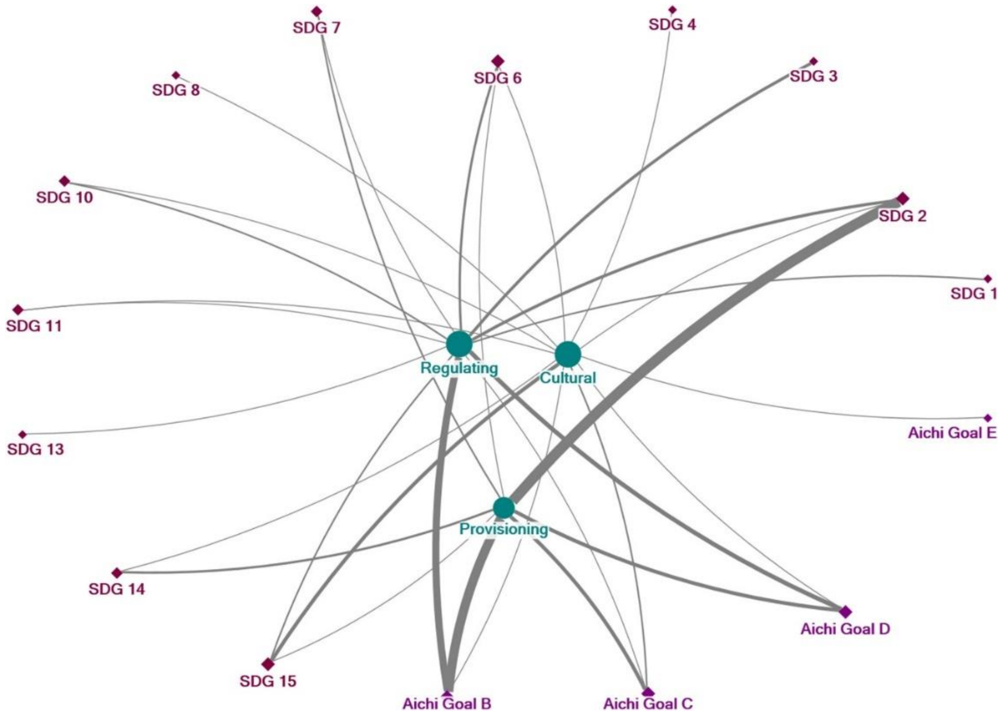


Figure 2-2 Relative importance of ES categories for the different policy objectives (Geijzendorffer et. al. 2017)

Other interesting findings on the topic comes from Wood et. al, 2018 that analysed the perceived level of support of ecosystem services to each SDG target based on responses of surveyed experts. Interestingly, the 12 SDGs considered by Wood and evaluated by the surveyed experts do not correspond exactly with the findings from Geijzendorffer. According to Geijzendorffer, both SDG4 – quality education- and SDG10 - reduced inequality – included references to cultural and regulating services, while these are not mentioned in the Wood analysis. This difference could lie in the fuzzier interpretation of the cultural services, specifically in relation with their educational, social relation, and justice related value. Indeed, such services have been recognized by some authors (Gómez-Baggethun & Barton, 2013; Wallace, 2007), but they are not formally recognized in the Millennium Ecosystem Assessment or in the TEEB. Also, the methods for their assessment and evaluation have not been standardized yet and further research on tools and methods would then be required, as further explored in this work (Chapter 6).

At the same time Wood et al. 2018 considered ecosystem services possibly relevant for two targets of SDG9 – resilient infrastructure - and 4 targets of SDGs 12 – responsible production and consumption, mostly in relation with provisioning services such as food production and water provision (see Fig. 2-3), that have not been considered by Geijzendorffer et al. 2017.

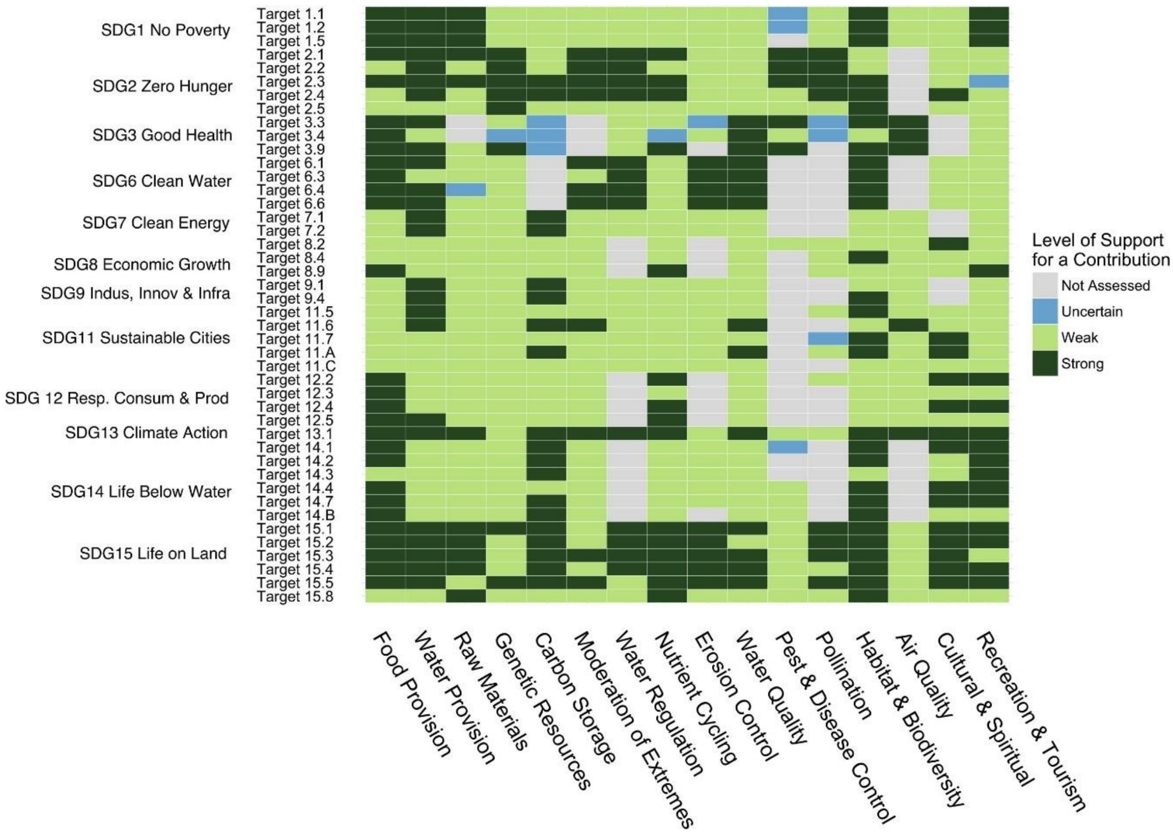


Figure 2-3 Perceived level of support for Ecosystem services contributions to SDGs targets (Wood et al. 2018)

Of the 12 SDGs considered in the survey, SDG2 Zero Hunger, SDG14 Life Below Water and SDG15 Life on Land, have been stronger related with ecosystem service contributions. Similarly, ecosystem services appear to make important contributions to SDG6 Clean Water and SDG11 Sustainable Cities targets. Provision of food and water and habitat & biodiversity maintenance services were the most frequently perceived as contributing to the greatest number of distinct targets (21, 21 and 26 targets respectively) followed by carbon storage & sequestration (14). Water quality, water regulation, raw material provisioning and recreation & tourism each contributed to 10 or more targets. Goals SDG1 No Poverty, SDG2 Zero Hunger, SDG6 Clean Water and SDG15 Life on Land were thought to receive the greatest number of distinct ecosystem services contributions. Strong contribution of different ESs, specifically water provision, carbon storage, water quality, habitat ad biodiversity and cultural and spiritual, were recognized for SDG11 on sustainable cities and communities. Oddly, the recreation and tourism service were not considered to play a strong role towards SDG 11, while recreational value is very much connected with citizens' health and wellbeing. Indeed, as also stated by Kleinert and Horton 2016, what it is merely implied within SDGs targets and goals, and not explicitly mentioned, is health and wellbeing for city inhabitants.

The SDG endorsement of the new stand-alone urban goal to make cities safe, inclusive, resilient, and sustainable (henceforth SDG11) is path breaking since it concedes that, in an urban world, cities can be pathways to sustainable development. Also, the scoping of target 11.3 on the role of green urban areas in cities represent a powerful tool to boost cities to invest in urban ecosystems and nature-based solutions. Nevertheless, the missed reference to citiziens and their role as beneficiaries and prosumers of the benefits provided by green spaces is probably a missed opportunity.

Target 11.7 By 2030, provide universal access to safe, inclusive, and accessible green and public spaces, in particular for women and children, older persons and persons with disability	Indicator 11.7.1: Average share of the built-up area of cities that is open space for public use for all, by sex, age and persons with disabilities

It is anyway worth highlighting that the work on indicators and is still on process and the UN will make further improvement on those in the following years. While the work towards SDGs was in its core, there is no doubt that the COVID-19 pandemic has shaken the 2030 Agenda for Sustainable Development to its very essence (United Nations, 2020). However, the principles on which the SDGs were established are key to building back better in the post-COVID-19 recovery. The continued pursuit of these universal Goals will keep Governments focused on growth, but also on inclusion, equity and sustainability. The countries collective response to the pandemic can serve as a "warm-up" for our preparedness in preventing an even larger crisis – that is, global climate change, whose effects are already becoming too familiar.

2.4 THE ROLE OF CITIES AND LOCAL COMMUNITIES INTO GLOBAL SUSTAINABLE DEVELOPMENT

Urban areas, with more than 60% of world population living in cities, are facing challenges due to overpopulation, social inequalities, environmental challenges, and limited available resources, resulting often in unsustainable development trajectory. The need of urban responses, in terms of local sustainable and resilient policies and strategies, raised at international level during the Earth Summit in Rio with the Agenda 21 (United Nations, 1992c), and followed through the United Nations Conference on Human Settlements- Habitat II, finally received its international endorsement just in

2015 with the inclusion of a new stand-alone urban goal – SDGs 11 – and followed in 2016 with the definition of the New urban Agenda (UN, 2016). Paths to local sustainability determined by cities would largely contribute to the realization of the global sustainable development goals and international climate and biodiversity targets.

2.4.1 AGENDA 21 AND LOCAL AGENDA 21

As already acknowledged in previous paragraph, the Earth Summit in Rio represents a crucial milestone in the development of climate, biodiversity, and sustainable development global policies. The United Nations Conference on Environment & Development also paved the way to influence local policies for development of sustainable cities and communities. Agenda 21 (United Nations, 1992c) is one of the four outputs of the summit, developed as a non-binding action plan to be implemented in accordance with the Rio Declaration. *Agenda 21 addresses the pressing problems of today and also aims at preparing the world for the challenges of the next century.* Agenda 21 is constituted of 3 sections tackling the socio-economic (section I), the environmental and biological components (section II) of sustainable development and the role of the so-called Major Groups (section III) to achieve it.

Within Section 1, Chapter 7 is dedicated to promoting sustainable human settlement development.

Human settlement conditions in many parts of the world, particularly the developing countries, are deteriorating and [..] the environmental implications of urban development should be recognized and addressed in an integrated fashion by all countries, with high priority being given to the needs of the urban and rural poor, the unemployed and the growing number of people without any source of income. Among other relevant programme areas for human settlement, such as adequate housing and human resources development, at least four categories could be achieved with the support of ecosystem services and nature-based solutions: i) Promoting sustainable land-use planning and management ii) Promoting the integrated provision of environmental infrastructure: water, sanitation, drainage and solid-waste management iii) Promoting human settlement planning and management in disaster-prone areas iv) Promoting sustainable construction industry activities.

Agenda 21 introduced another necessary step towards local sustainable development enouncing the need to integrate environment and development in decision making, specifically *a) integrating environment and development at the policy, planning and management levels and b) providing an effective legal and regulatory framework*. Such statement, that could appear obvious nowadays, was extremely innovative at the time and succeeded, through the last 30 years, at changing the mindsets not just of decision makers, but also of entrepreneurs and investors that more and more include the environmental components into the decision taken over private and public processes. This is probably the biggest outcome of the Earth summit, managing to include the environmental dimension as one of the spheres of sustainable development together with and at the same level of the economic and the social components. Chapter 9 to 22 developed on conservation and management of resources for sustainable development and touched upon many sectors that could be improved by a better management of ecosystem and their services or through new nature based solutions such as: protection of the atmosphere (air filtering and CO2 regulation through conservation of or new ecosystems and trees), combating deforestation (carbon storage, CO2 regulation through conservation of or new ecosystems and trees), managing fragile ecosystems: combating desertification and drought (water management through natural water retention measures), promoting sustainable agriculture and rural development (sustainable food production) conservation of biological diversity (genetic diversity through ecosystem conservation, protection and enhancement), protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources (water management, mangrove restoration or enhancement, natural wetlands protection or enhancement). Chapter 28 is the most relevant chapter in terms of local sustainable development policies and trajectory. It focusses on the role of local authorities, stakeholders and public into sustainable planning and development stating that since *many of the problems and solutions addressed by Agenda 21 have their roots in local activities, the participation and cooperation of local authorities will be a determining factor in fulfilling its objectives. Local authorities construct, operate and maintain economic, social and environmental infrastructure, oversee planning processes, establish local environmental policies and regulations, and assist in implementing national and subnational environmental policies. As the level of governance closest to the people, they play a vital role in educating, mobilizing and responding to the public to promote sustainable development.* In this regard one, major objective of the Agenda 21 initiative is that every local government should draw its own local Agenda 21 as a result of a participatory process with local stakeholders and communities. The participatory process towards local environmental action plans includes the establishment of a local forum for permanent consultation, the evaluation of current state of the environment, the definition of agreed objectives and priorities and of adequate monitoring and assessment indicators. According to Connelly, 2014 more than 10.000 local communities initiated their local forum and develop their local Agenda 21 (LA21). Despite the absence of an overall picture of the programme implementation at local level over 1,700 local government members from over 90 countries committed to sustainable development and implementation of LA21 processes through their membership to ICLEI – Local Governments for Sustainability – that born in 1990 with the ambition of supporting local government in the Agenda 21 planning and implementation. Europe was without doubts the continent with the greatest participation in the programme with almost 6000 sustainability plans developed against 100 for North American communities and around 20 for Indian communities (Smardon, 2008). LA21 in Europe have been considered effective frameworks for enhancing local sustainability policies, capacity building within local communities, and improving innovation in local government and decision-making processes (Sancassiani, 2005). Nevertheless, the reason for such a success could lie in an extensive support network built in Europe (Smardon, 2008)and it is contended that LA21 has its limitations as a planning guide for sustainable cities in developing countries (Tonami & Mori, 2007).

2.4.2 THE HABITAT II, THE NEW URBAN AGENDA AND HABITAT III

In parallel with the implementation of the Agenda 21 that involve local communities, such as rural indigenous communities, as well as urban area, and megalopolis, the Habitat conferences, with its first meeting in Vancouver in 1976, became the mechanisms that defined and then institutionalized the evolving influence of progressive voices on sustainability and urban questions globally. Table 2-3 summarized the main milestones from 1992 to Habitat III (2016).

Table 2-3 Evolution of the concept and the role of cities in UN milestones for urban agenda from 1992 to Habitat III

UN MILESTONES	EVOLVING CONCEPTS OF CITIES	STRATEGIES FOR URBAN DEVELOPMENT	NEW URBAN DEVELOPMENT PROGRAMS, PRACTICES & FRAMEWORKS (OUTCOMES)
UNCED 1992 Agenda 21	_ Cities and urban growth as problems _ Sustainable urban and rural development _ Local communities' recognition	_ Local authority and local stakeholder engagement and collaboration _ More integrated local planning	_ Local Agenda 21 (i.e., urban sustainability planning) _ Integrated (Development) Planning
Habitat II 1996	_ Cities as growth and development centres _ Focus on ''mega-cities"	_ Inclusive Cities _ Good Urban Governance _ Public–Private partnerships	_ City Development Strategies, _ Cities Alliance _ Cities Without Slums
Habitat III	_ Inclusive cities "right to the city" _ Resilient Cities _Safe and sustainable cities _Cities as source of solutions _Social function of cities	_ People-centred, age- and gender-responsive policies and planning _ Smart city approach _ Regional (Rural–Urban) Integration _Nature based solutions, and innovation, Ecosystem-based approaches	UN-Habitat's City prosperity Initiative (CPI)

Habitat I was a product of the UN Conference on the Human Environment in Stockholm in 1972. Whereas Stockholm was about international environmental problems, Habitat I was convened to address local environmental problems, such as housing, shelter, infrastructure, water, sewage, transport, etc. The three major accomplishments of Habitat I were: 1) to strongly encourage all governments to consider human geography in their development policies and to establish ministries and agencies responsible for territorial planning and management, 2) to establish a United Nations Centre for Human Settlements, which would be based in Nairobi, Kenya, and 3) to encourage the creation of civil society organizations focused on urban issues. In 1996 United Nations Conference on Human Settlements met in Istanbul, Turkey in a meeting that was then commonly called the "City Summit"(United nations, 1996). During the summit parties agreed *on a long-term objective of arrest the deterioration of global human settlements conditions and create the conditions for achieving improvements in the living environment of all people on a sustainable basis*. While Habitat I mostly focused on territorial planning and housing, without highlighting the environment and the ecological component, Habitat II had recognized the urban environment, but had not gone far enough to raise the alarm on climate change and resource depletion, rather focusing on good environmental management of urban nexus. Despite the broad participation of civil society groups and the recognition of the critical role of local government organizations and planning in developing sustainable human settlements, Habitat II didn't reach the expected results due to the same nature of a non-binding agreement and also due a weak monitoring system (Cohen, 2016).

The discussion towards a new Habitat agreement on sustainable human settlement took 20 years and built on various crucial meetings and agreements such as the Millennium Development Goals (2000) Rio+20 (2012), the Paris Agreement and the Sustainable Development Goals (2015) and a series of preparatory Commission (2014, 2015, 2016). In October 2016, government officials and urban advocates met in Quito, Ecuador, to attend the United Nations (U.N.) Conference on Housing and Sustainable Development (Habitat III). There, the Habitat III delegates discussed the New Urban Agenda, a document detailing the vision for the future of urban areas, but also implementation and action plans to follow (United Nations 2016). The document is divided into 3 different sections: commitments, effective implementation, and follow-up and review.

The planning and managing of urban areas and other human settlements is detailed in the document defining the priorities for the future of sustainable urban areas. The Agenda endorses creating compact, mixed-use, and connected cities dealing with population increases and it calls for planning that supports the food–water–energy nexus (Birch, 2016) and for better, safer and more quality housing for all. The implementation of the New Urban Agenda (NUA) should contribute of the 2030 Agenda for Sustainable Development in an integrated manner, and primarily to the achievement of the Sustainable Development Goals and targets, including Goal 11 of making cities and human settlements inclusive, safe, resilient and sustainable.

Concerning ecosystems and the ecological components of urban systems, the NUA aims at *cities and human settlements that fulfil their social function, including the social and ecological function of land [..] and protect, conserve, restore and promote their ecosystems, water, natural habitats and biodiversity, minimize their environmental impact and change to sustainable consumption and production patterns.* The NUA claims for *readdressing the way we plan, finance, develop, govern and manage cities and human settlements, recognizing sustainable urban and territorial development as essential to the achievement of sustainable development and prosperity for all* and for *adopting sustainable, people-centred, age- and gender-responsive approaches to urban and territorial development,* leaving no one behind in human settlements. The NUA explicitly mentioned ecosystem services, nature-based solutions and innovation and ecosystem-based approach, in line with the raise of the term Nature Based Solutions from 2013 in science, practice and policies' language. Signatories of the NUA commit *to promote safe, inclusive, accessible, green and quality public spaces.* For the first time in international policies the NUA defines green space as *multifunctional areas for social interaction and inclusion, human health and well-being, economic exchange and cultural expression and dialogue among a wide diversity of people and cultures, designed and managed to ensure human development and build peaceful, inclusive and participatory societies, as well as to promote living together, connectivity and social inclusion*. The diverse 'functions' of green areas in the urban socio-ecological system, are limited, in this sentence, to cultural ecosystem services, uses and benefits highlighting social inclusion and cohesion, human wellbeing and health and economic benefit. At the same time, *well-connected and well distributed networks of open, multipurpose, safe, inclusive, accessible, green and quality public spaces* are recognized to improve *the resilience of cities to disasters and climate change, including floods, drought risks and heat waves, to improving food security and nutrition, physical and mental health, and household and ambient air quality, to reducing noise and promoting attractive and liveable cities, human settlements and urban landscapes and to prioritizing the conservation of endemic species* thus recognizing also the regulating and provisioning functions of urban ecosystems. Also, the NUA directly refers to nature-based solutions as a mean of integrating disaster risk reduction and climate change adaptation and mitigation considerations and measures and claims for *supporting science, research and innovation, including a focus on social, technological, digital and nature-based innovation.*

The New Urban Agenda recognized not just the value of green spaces, but also of blue infrastructures such as urban deltas and coastal areas as crucial ecosystems' providers and commit to preserve and promote the ecological an social functions of land, *promoting sustainable land use, combining urban extensions with adequate densities and compactness to prevent and contain urban sprawl, as well as preventing unnecessary land-use change and the loss of productive land and fragile and important ecosystems*.

In parallel with the New Urban Agenda, several international initiatives are raising in the last years, such as the 100 resilient cities of the Rockefeller foundation that aims at developing dedicated resilience strategy for each city, the C40 network, that aims at complying with Paris agreement target of 1.5°. The arise of such initiatives demonstrates the growing interest of the same cities to improve citizens quality of life, health and wellbeing, but also to play a leading role in the transition towards more just and green future. As already mentioned for the SDGs implementation, the current urban transition towards sustainable and just future could brake due to the current COVID-19 crisis that would most probably need most of the resources now available at city level. Conversely, the pandemic can be turned into another driver to go towards a more just and sustainable future and some cities are already undertaking this opportunity, as stated in the C40 Mayors' agenda for a green and just recovery (C40, 2020).

2.5 CONCLUSIONS

Even though international agreements remain non-binding and voluntary instruments, their relevance and rebound heavily influence the public opinion over the last 50 years. Triggering both top-down (active national governments) and bottom up (initiatives from NGOs and the civil society) approaches, international agreements should encourage national governments to set up national strategies that embed ecosystem-based planning approaches and nature-based solutions, pushing for nature-based innovations and transformation. The issue of developing just and fair agreements and strategies for the Global North and South remains, when a deeper consultation approach including even more the civil society and non-governmental organizations would be needed.

The history of international agreements on climate, biodiversity and sustainable development, shows that since the early 70s the United Nations recognized the need to intervene to modify current unsustainable trajectories acknowledging the role of humans in natural resources depletion and pollution. Since the Stockholm declaration,1072, the value of ecosystem and of natural environment are recognized as crucial for human life and wellbeing. Most of the documents that were developed prior to the policy uptake of the Ecosystem Services framework, refer to nature and ecosystem as crucial element for human wellbeing and specific ES are mentioned into diverse policies (carbon sequestration for climate policies, regulation of natural hazards for sustainable development, and habitat for biodiversity). At the same time, the work around the development of sustainable and just settlements, among which urban areas, became the priority of the UN Habitat Commission and contributed throughout the years to empower cities, local authorities and the civil society as a whole.

The role of cities as major actors of sustainable transition has been clearly recognized since 2015, dedicating to urban sustainable development and transition one of the new SDGs. Also, the New Urban Agenda represent a well-advanced strategic document, that not only recognises the need of renaturing and greening cities to run toward urban sustainability and just and inclusive societies, but it also acknowledges the role of urban and territorial planning as crucial instruments in this transition. Also, the New Urban Agenda well reflects the latest scientific research and recognize the crucial role of urban green spaces for their multifunctionality inviting local authorities to consider and evaluate the multiple benefits and co-benefits they provide. In this sense, as highlighted by several scholars (Milcu, Hanspach, Abson, & Fischer, 2013; Satterfield, Gregory, Klain, Roberts, & Chan, 2013; Villamagna, Angermeier, & Bennett, 2013) further work is needed to define tools, instruments, and assessment methods to better assess Cultural Ecosystem Services and to integrate them into urban and spatial planning.

Looking at climate policies, the Paris Agreement (United Nations, 2015b) does not include any specific reference to nature-based solutions or cities, even though NBS at urban level can be considered a valuable alternative to cost-effective climate adaptation measures. Indeed, while the recognition of the role of forests and re-forestation as a crucial policy measure to increase global mitigation target was already acknowledged in previous climate agreements, the increasing significance of climate adaptation measures, rather than mitigation, could also boost the role of nature and ecosystems as appropriate measures to be implemented in national adaptation and mitigation strategies and plans, and further transferred at local level. On the biodiversity side, whether nature-based solutions are well-recognized and acknowledged in the Aichi target for Biodiversity and in the Sustainable Development Goals, a comprehensive ecosystem services-based approach for planning is not properly addressed- i.e in the national biodiversity plan or in the definition of measures to be applied to reach the SDGS.

Despite the recognized limitation of some of the international agreements, we do recognize their potential in boosting a sustainable urban transition. Nevertheless, nowadays, the main question would be whether the attention on climate, biodiversity and sustainable development issues will be shifted for the next years, overshadowed by current health and economic crisis. On the other side, the current COVID-19 pandemic could boost international cooperation towards a broader understanding of the prevention principle, considering the current situation as a “warm-up” for our preparedness in preventing an even larger crisis – that is, global climate change, whose effects would be even more devasting than the current pandemic ones.

LIST OF REFERENCES

Bader, C., Bieri, S., Wiesmann, U., & Heinimann, A. (2017). Is Economic Growth Increasing Disparities? A Multidimensional Analysis of Poverty in the Lao PDR between 2003 and 2013. *Journal of Development Studies*, *53*(12), 2067–2085. https://doi.org/10.1080/00220388.2016.1251587

Bauer, A. M., & Ellis, E. C. (2018). The anthropocene divide: Obscuring understanding of social-environmental change. *Current Anthropology*, *59*(2), 209–227. https://doi.org/10.1086/697198

Biggs, R., Schlüter, M., & Schoon, M. L. (2015). Principles for building resilience: Sustaining ecosystem services in social-ecological systems. In *Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems*. https://doi.org/10.1017/CBO9781316014240

Birch, E. L. (2016). A Midterm Report: Will Habitat III Make a Difference to the World's Urban Development? *Journal of the American Planning Association*, *82*(4), 398–411. https://doi.org/10.1080/01944363.2016.1216326

C40. (2020). *C40 Mayors' Agenda for a Green and Just Recovery - Global mayors COVID-19 recovery task force* (p. 43). p. 43.

Carson, R. (1962). Silent Spring. Houghton Mifflin, United States.

Cohen, M. A. (2016). From Habitat II to Pachamama: a growing agenda and diminishing expectations for Habitat III. *Environment and Urbanization*, *28*(1), 35–48. https://doi.org/10.1177/0956247815620978

Connelly, S. (2014). Local Agenda 21: International Council for Local Environmental Initiatives. In A. C. Michalos (Ed.), *Encyclopedia of Quality of Life and Well-Being Research* (pp. 3670–3673). https://doi.org/10.1007/978-94-007-0753-5_1681

Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., … Grasso, M. (2017). Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services*. https://doi.org/10.1016/j.ecoser.2017.09.008

Cowling, R. M., Egoh, B., Knight, A. T., O'Farrell, P. J., Reyers, B., Rouget, M., … Wilhelm-Rechman, A. (2008). An operational model for mainstreaming ecosystem services for implementation. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(28), 9483–9488. https://doi.org/10.1073/pnas.0706559105

Crutzen, P. J. (2002). Geology of mankind. *Nature*, *415*(6867), 23. https://doi.org/10.1038/415023a

Cuevas, C. A., Maffezzoli, N., Corella, J. P., Spolaor, A., Vallelonga, P., Kjær, H. A., … Saiz-Lopez, A. (2018). Rapid increase in atmospheric iodine levels in the North Atlantic since the mid-20th century. *Nature Communications*, *9*(1), 1–6. https://doi.org/10.1038/s41467-018-03756-1

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M. A., … Von Der Dunk, A. (2012). Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(23), 8812–8819. https://doi.org/10.1073/pnas.1114773109

del Monte-Luna, P., Brook, B. W., Zetina-Rejón, M. J., & Cruz-Escalona, V. H. (2004). The carrying capacity of ecosystems. *Global Ecology and Biogeography*, *13*(6), 485–495.

https://doi.org/10.1111/j.1466-822X.2004.00131.x
Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., … Le Roux, X. (2015). Nature-based solutions: New influence for environmental management and research in Europe. *Gaia*, *24*(4), 243–248. https://doi.org/10.14512/gaia.24.4.9
EU Commission. (2013). *Green Infrastructure (GI) — Enhancing Europe's Natural Capital*.
EU parliament. (2001). *Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (OJ L 197 21.07.2001 p. 30)*. https://doi.org/10.1017/cbo9780511610851.021
European Council. (1985). *Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment 85/33 7/EEC*. (L), 220–234. https://doi.org/10.1680/ea.26124.bm01
Everett, T., Ishwaran, M., Ansaloni, G. P., & Rubin, A. (2010). *Economic Growth and the Environment - Defra Evidence and Analysis Series - paper 2*. https://doi.org/10.3386/w14522
Falkner, R. (2016). The Paris agreement and the new logic of international climate politics. *International Affairs*, *92*(5), 1107–1125. https://doi.org/10.1111/1468-2346.12708
Fisher, B., Turner, K., Zylstra, M., Brouwer, R., De Groot, R., Farber, S., … Balmford, A. (2008). Ecosystem services and economic theory: Integration for policy-relevant research. *Ecological Applications*, *18*(8), 2050–2067. https://doi.org/10.1890/07-1537.1
Geijzendorffer, I. R., Cohen-Shacham, E., Cord, A. F., Cramer, W., Guerra, C., & Martín-López, B. (2017). Ecosystem services in global sustainability policies. *Environmental Science and Policy*, *74*(January), 40–48. https://doi.org/10.1016/j.envsci.2017.04.017
Geijzendorffer, I. R., Martín-López, B., & Roche, P. K. (2015). Improving the identification of mismatches in ecosystem services assessments. *Ecological Indicators*, *52*, 320–331. https://doi.org/10.1016/j.ecolind.2014.12.016
Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019
Gupta, J. (2010). A history of international climate change policy. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(5), 636–653. https://doi.org/10.1002/wcc.67
Hoornweg, D., Hosseini, M., Kennedy, C., & Behdadi, A. (2016). An urban approach to planetary boundaries. *Ambio*, *45*(5), 567–580. https://doi.org/10.1007/s13280-016-0764-y
IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *IPCC, Geneva, Switzerland, 151 Pp.* https://doi.org/10.1016/S0022-0248(00)00575-3
Jordan, A., & Voisey, H. (1998). The "Rio Process": The politics and substantive outcomes of "Earth Summit II." *Global Environmental Change*, *8*(1), 93–97. https://doi.org/10.1016/S0959-3780(97)00024-1
Kavalski, E., & Zolkos, M. (2016). The recognition of nature in international relations. *Recognition and Global Politics: Critical Encounters Between State and World*, 139–155. https://doi.org/10.7228/manchester/9781784993337.003.0008
Kleinert, S., & Horton, R. (2016). Urban design: an important future force for health and wellbeing. *The Lancet*, *388*(10062), 2848–2850. https://doi.org/10.1016/S0140-6736(16)31578-1

Leal-Arcas, R., & Carafa, L. (2014). Road to Paris COP21: Towards Soft Global Governance for Climate Change? *Renewable Energy Law and Policy Review*, *5*(2), 128–133.

Lenton, T. M., & Williams, H. T. P. (2013). On the origin of planetary-scale tipping points. *Trends in Ecology and Evolution*, *28*(7), 380–382. https://doi.org/10.1016/j.tree.2013.06.001

Milcu, A. I., Hanspach, J., Abson, D., & Fischer, J. (2013). Cultural ecosystem services: A literature review and prospects for future research. *Ecology and Society*, *18*(3). https://doi.org/10.5751/ES-05790-180344

Millenium Ecosystem Assessent. (2005). *Ecosystems and Human Well-being: Synthesis*. https://doi.org/10.5822/978-1-61091-484-0_1

Newman, P. A., Oman, L. D., Douglass, A. R., Fleming, E. L., Frith, S. M., Hurwitz, M. M., … Velders, G. J. M. (2009). What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated? *Atmospheric Chemistry and Physics*, *9*(6), 2113–2128. https://doi.org/10.5194/acp-9-2113-2009

Nicholson, E., MacE, G. M., Armsworth, P. R., Atkinson, G., Buckle, S., Clements, T., … Milner-Gulland, E. J. (2009). Priority research areas for ecosystem services in a changing world. *Journal of Applied Ecology*, *46*(6), 1139–1144. https://doi.org/10.1111/j.1365-2664.2009.01716.x

Raymond, C. M., Pam, B., Breil, M., Nita, M. R., Kabisch, N., de Bel, M., … Calfapietra, C. (2017). An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. In *EKLIPSE*.

Robert, L. (1980). Carrying capacity- understanding our biological limitations. Humboldt Journal of Social Relations , Spring / Summer 1980 , Vol . 7 , No . 2 Published by : Department of Sociology , Humboldt State University Sta. 7(2), 55–70.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., … Foley, J. (2009). Planetary boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, *14*(2). https://doi.org/10.5751/ES-03180-140232

Sancassiani, W. (2005). Local agenda 21 in Italy: An effective governance tool for facilitating local communities' participation and promoting capacity building for sustainability. *Local Environment*, *10*(2), 189–200. https://doi.org/10.1080/1354983052000330770

Satterfield, T., Gregory, R., Klain, S., Roberts, M., & Chan, K. M. (2013). Culture, Intangibles and metrics in environmental management. *Journal of Environmental Management*, *117*, 103–114. https://doi.org/10.1016/j.jenvman.2012.11.033

Smardon, R. C. (2008). A comparison of Local Agenda 21 implementation in North American, European and Indian cities. *Management of Environmental Quality: An International Journal*, *19*(1), 118–137. https://doi.org/10.1108/14777830810840408

Soroos, M. S. (2001). Global Climate Change and the Futility of the Kyoto Process. *Global Environmental Politics*, Vol. 1, pp. 1–9. https://doi.org/10.1162/152638001750336541

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., … Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences of the United States of America*, 201810141. https://doi.org/10.1073/pnas.1810141115

Sterner, T., Barbier, E. B., Bateman, I., van den Bijgaart, I., Crépin, A. S., Edenhofer, O., …

Robinson, A. (2019). Policy design for the Anthropocene. *Nature Sustainability*, *2*(1), 14–21. https://doi.org/10.1038/s41893-018-0194-x

Strahan, S. E., & Douglass, A. R. (2018). Decline in Antarctic Ozone Depletion and Lower Stratospheric Chlorine Determined From Aura Microwave Limb Sounder Observations. *Geophysical Research Letters*, *45*(1), 382–390. https://doi.org/10.1002/2017GL074830

Streck, C. (2020). The mirage of Madrid: elusive ambition on the horizon. *Climate Policy*, *20*(2), 143–148. https://doi.org/10.1080/14693062.2020.1726564

Tonami, A., & Mori, A. (2007). Sustainable development in Thailand: Lessons from implementing local agenda 21 in three cities. *Journal of Environment and Development*, *16*(3), 269–289. https://doi.org/10.1177/1070496507306223

UN. (2016). *New urban agenda - Habitat III*.

UNEP. (2010). *The Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets*. (October 2010), 493–499. https://doi.org/10.1007/978-90-481-9659-3_119

UNFCCC. (1997). *UNITED NATIONS Kyoto Protocol*. 1–24.

United nations. (1987). Montreal Protocol on Substances that Deplete the Ozone Layer Montreal, 16 September 1987. *United Nations Treaty Collection*, *C*(September).

United nations. (1996). *Report of the United Nations Conference on Human Settlements (Habitat II)*. https://doi.org/10.3828/twpr.18.2.31j73k7581432t10

United Nations. (1948). *United Nations Human Rights Declaration*.

United Nations. (1972). United Nations Conference on the Human Environment [UNCHE]. Stockholm Declaration: A/CONF.48/14/Rev.1. *Report of the United Nations Conference on the Human Environment*, (June), 77.

United Nations. (1992a). *Convention on Biological Diversity*. https://doi.org/10.1016/B978-0-12-384719-5.00418-4

United Nations. (1992b). *Report of the United Nations Conference on Environment and development: Rio Declaration on Environment and Development*.

United Nations. (1992c). *UN Conference on Environment and Development Rio de Janeiro, Brazil, 3 to 14 June 1992 - Agenda 21*. *6*(June), 47–54. https://doi.org/10.4135/9781412971867.n128

United Nations. (1992d). *United Nations Framework Convention on Climate Change*.

United Nations. (2015a). *Millenium Development Goals Report*. (June), 1.

United Nations. (2015b). *Paris Agreement*.

United Nations. (2015c). *Resolution adopted by the General Assembly on 25 September 2015 - Transforming our world: the 2030 Agenda for Sustainable Development*. https://doi.org/10.1163/157180910X12665776638740

United Nations. (2020). *The sustainable development goals report 2020*. https://doi.org/10.29171/azu_acku_pamphlet_k3240_s878_2016

Villamagna, A. M., Angermeier, P. L., & Bennett, E. M. (2013). Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. *Ecological Complexity*, *15*, 114–121. https://doi.org/10.1016/j.ecocom.2013.07.004

Wallace, K. J. (2007, October 1). Classification of ecosystem services: Problems and solutions. *Biological Conservation*, Vol. 139, pp. 235–246. https://doi.org/10.1016/j.biocon.2007.07.015

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*. https://doi.org/10.1016/j.landurbplan.2014.01.017

Wood, S. L. R., Jones, S. K., Johnson, J. A., Brauman, K. A., Chaplin-Kramer, R., Fremier, A., … DeClerck, F. A. (2018). Distilling the role of ecosystem services in the Sustainable Development Goals. *Ecosystem Services*, *29*, 70–82. https://doi.org/10.1016/j.ecoser.2017.10.010

World Commission on Environment and Development. (1987). *The Brundtland Report: "Our Common Future."* https://doi.org/10.1080/07488008808408783

WMO - World Meteorological Organization. (2019) Twenty Questions and Answers About the Ozone Layer: 2018 Update, Scientific Assessment of Ozone Depletion: 2018, Geneva, Switzerland, 84 pp.

3 THE RECOGNITION OF NATURE AND CITIES' ROLE INTO THE EUROPEAN NORMATIVE FRAMEWORK

ABSTRACT

Following the 1972 Stockholm Declaration, the European heads of state and government decided to establish the first environmental action program, marking the official beginning of a European environmental policy. Since then, the EU's environmental policy has developed into a comprehensive and complex regime. The European Commission then started in the 1990s to act as a supranational institution representing the EU in international environmental treaty negotiations, including the promotion of its own policy models at the international level. The European policy framework, including the recently released European Green Deal, could strongly boost the role and recognition of nature and cities as drivers of sustainable and inclusive urban transition. This chapter does not pretend to summarize the overall European environmental policy framework, neither is in the scope of this work to analyse the institutional, constitutional, or law-making mechanisms behind it. The aim of this chapter is rather to present current European policies that relate with the main topic of this thesis, i.e ecosystem services and nature-based solutions for urban sustainability and resilience, and to highlight current gaps and possible future development for better regulation.

3.1 THE RECOGNITION OF NATURE AND CITIES ROLE INTO THE EUROPEAN NORMATIVE FRAMEWORK

The history of European environmental policies laid its basis in the original European Economic Community Treaty (ECC, 1957) that did not contain explicit reference regarding EU competences on environmental issues but did include references on *raising standard of living* and *constant improvement of living and working conditions of people*, in line with the rights developed within the Human Right Declaration of 1948. However, Europe, as well as the international community, could not overlook the raising public environmental concern in the late 60s. Following the 1972 Stockholm Declaration, the European heads of states and governments decided to establish the first environmental action program, at the European Council in Paris. This event marked the official beginning of a European environmental policy (Holzinger & Sommerer, 2014). Since then, the EU's environmental policy has developed into a comprehensive and complex regime and through the former article 130, now article 192-193, of the Treaty on the Functioning of European Union, the Council was entitled with specific competencies over environmental policy. Also, after 1990 the European Commission started to act as a supranational institution representing the EU in international environmental treaty negotiations and beginning to promote its own policy models at the international level (Holzinger & Sommerer, 2014).

This Chapter will briefly present policies' objective and the potential role of ES and NBS in reaching such objectives. In the scope of this work policies both refer to binding legislation (e.g. directives, regulations and decision) and non-binding strategies and programme (e.g. strategies, action plans and programmes) (Bouwma et al., 2017). Following the sectorial division of the EU Commission within DG Environment, European policies analysed have been divided in the following sectors:

- Environment as an overarching issue
- Biodiversity
- Climate Change
- Water
- Coastal areas and Marine environment
- Circular economy
- Environmental Impact
- Public Procurement

For each sector, the main legislative documents have been analysed to verify and assess the relevance and the role of the natural and urban environment, looking for:

- General or specific reference to the role of nature in the achievement of defined targets (specific ecosystem services and nature-based solutions references);
- General or specific reference to the urban environment and its role in the achievement of defined targets.

A short summary has been developed for the different sectors and for each policy, summarizing the aim of the main policies and their link to ecosystem services/NBS and urban issues. Consistent with (Geneletti & Zardo, 2016; Rozas-Vásquez, Fürst, Geneletti, & Almendra, 2018), this policy screening did not employ a strict keyword-based content analysis, but it relied on both explicit and non-explicit qualitative content analysis. In the conclusion, judgments on the level of incorporation of the role of nature and urban sustainability in the analysed policies will be translated into a quantitative assessment using a score from 1 (low incorporation) to 3 (high incorporation) to facilitate the final representation of the results. The tables detailing and summarizing the different policies can be found in Annex 1.

3.2 ENVIRONMENT AS AN OVERARCHING ISSUE

The first EU Environmental Action Programme (EAP) was developed and approved in 1972 and defined thematic priorities and objectives for the following seven years. From that moment, the European Union developed seven EAPs and is now in the process of defining the 8th programme that will cover from 2021 to 2028.

In the 7th EAP, running from 2013 to 2020 (EU parliament, 2013) the importance of cities' transition towards sustainability is not well highlighted and recognized, despite citizens' health and wellbeing was included as one of the thematic priorities. The role of nature in reaching thematic priorities is clearly recognized, mostly linked to habitat preservation and connections and to climate change mitigation and adaptation. Nevertheless, protecting and conserving European biodiversity and nature remains the biggest area of discouraging progress (EEA, 2019). Of the 13 specific policy objectives set for 2020 in this area, only two are likely be met: designating marine protected areas and terrestrial protected areas.

According to the 'European environment — state and outlook 2020' report (EEA, 2019), while European environment and climate policies have helped to improve the environment over recent decades, Europe is not making enough progress and the outlook for the environment in the coming decade is not positive. Since the new European Commission settled in 2019, environmental issues and challenges have been placed as a top priority. The 8th EAP is currently under development but the first communication from the European Council (EU Council, 2019) clearly states the crucial role of ecosystems and of their service as a foundation of a fair, healthy and prosperous society. It is not clear how this programme will be developed, but it would be desirable, also in line with the New Urban Agenda, to include among the new thematic priorities one related with urban challenges and the role of nature and ecosystem into our cities. In this line, the 'EU guidance on integrating ecosystems and their services into decision-making'(EU Commission, 2019a) is a crucial step into this direction. Though the definition of 8 guiding principles this guidance aims at helping decision-makers who are seeking to improve the impact, cost-effectiveness and sustainability of their policies, plans and investments. The 8 guiding principles are: 1. Prioritise measures that improve ecosystem condition while contributing to well-being and prosperity for net societal gain. 2. Address the inter-dependencies and trade-offs. 3. Address potential negative impacts according to the mitigation hierarchy. 4. Apply the precautionary principle. 5. Set long-term objectives and plans for essential ecosystem processes. 6. Ensure adaptive management. 7. Coordinate and integrate planning across governance sectors, levels and decision-making frameworks. 8. Ensure stakeholder engagement. While this document provides clear and concrete guidelines to policy and decision makers, planners, and business, as explicitly mentioned in the document, due to its broad scope across a wide range of decision-making processes and target groups, the guidance provided in this document remains at a relatively general level (EU Commission, 2019).

At the same time, the EU Commission is now developing an ambitious programme that put sustainable and just development at the centre of European growth towards 2050. The so-called EU Green Deal represents the main new ambition of the EU Commission and it outlines a strategy for Europe to become the world's first climate-neutral continent by 2050. What is crucial to notice in the EU Green Deal is that environment is now at the centre of all other sectors, economy, development, energy, and justice. Current available documents, that will be individually analysed in different sectorial paragraphs, set the basis for a comprehensive policy framework encompassing the climate, energy, environmental, industrial, economic, and social aspects of this unprecedented process (Claeys, Tagliapietra, & Zachmann, 2019).

3.3 BIODIVERSITY

The recognition of the role of biodiversity and ecosystems' health into EU policies started in 1979 with the development of the Directive to protect wild birds' species and their habitats. Together with the Habitat Directive, 1992, these directives created the legislative base and identified the most valuable and threatened species and habitats for the development of the Natura 2000 network (EU Council, 1992). Natura 2000 is a network of core breeding and resting sites for rare and threatened species, and some rare natural habitat types which are protected in their own right. It stretches across all 27 EU countries, both on land and at sea and cover around 18% of EU land area and 6% of its marine territory (EU Commission, 2020). The connectivity of protected areas, such as the Natura 2000 network, is crucial for maintaining healthy ecosystems and for the delivery of ecosystem services into the wider landscapes and urban areas in which they are embedded (de la Fuente et al., 2018). Ecosystems' fragmentation is considered one of the main threats to ensure ecosystems' healthy and resilient provision of their services and the Nature 2000 sites represents the backbones of the so-called European Green Infrastructure. As previously mentioned, Green Infrastructure (GI) is *a strategically planned network of natural and semi-natural areas that provides multiple benefits to humans and environment* (EU Commission, 2013b). The protection, the maintenance, and the improvement of the current EU Green infrastructure can ensure multiple benefit at various scale supporting not just biodiversity and environmental targets, but also socio-economic objectives. The definition of the European Green Infrastructure is not a simple biodiversity and habitat related topic, as outlined in the Habitat and the Bird Directives, but a wider political issue that should be tackled at the appropriate political scale. For this reason, in 2012 the EU Commission released the European Green Infrastructure Strategy, where it recommends GI better integration and contribution to relevant topics such as regional policies, climate change, disaster risk management and Natural Capital (EU Commission, 2013b). The crucial role of GI in urban areas, where more than 60% of the EU population lived is well- recognized into the regional policies paragraph and have been highlighted by the Urban Agenda for the EU on Sustainable use of land and nature-based solutions, and other EU initiatives such as the European Green Capital and Green Leaf awards. EU. The 'Review of progress on implementation of the EU green infrastructure strategy' analyses the mainstreaming of GBI into other relevant policies and initiatives and stated that while '*there has been progress at various levels, challenges remain and the deployment of GI needs to be further scaled up. Evidence shows that a strategic approach for GI at EU level has not been implemented yet; and a more robust enabling framework for GI should be considered*'(EU Commission, 2019b). In this direction, within the EU Green Deal 'package', the EU Commission released the new Biodiversity strategy towards 2030, that acknowledged that Biodiversity loss and ecosystem collapse are one of the biggest threats facing humanity in the next years impacting environmental, socio-economic and health systems (EU Commission, 2020b). Adopted in the heart of the COVID-19 pandemic, this strategy is also a core element of the EU recovery plan, on the same line of current research that warns that habitat fragmentation and degradation, and live animal markets, increase the risk of diseases spilling over from wildlife into human populations (Corlett et al., 2020).The Commission's ambition is *to ensure that by 2050 all of the world's ecosystems are restored, resilient, and adequately protected in line with the 2030 Agenda for Sustainable Development and with the objectives of the Paris Agreement on Climate Change*. Nature-based solutions and ecosystem services are well integrated in the document as well as urban challenges and nature's role in sustainability transition. Specifically, paragraph 2.2.8 is dedicated to greening urban and peri-urban areas aiming at stopping the loss of green urban ecosystems. According to the strategy, the promotion of healthy ecosystems, green infrastructure and nature-based solutions *should be systematically integrated into urban planning, including public spaces, infrastructure, and the design of buildings and their surroundings*. In a stark comparison to the previous EU Biodiversity Strategy, cities are finally being recognised for the central role they play in safeguarding and enhancing biodiversity, and in providing green and blue corridors between larger areas of protected land. Also, cities with a population above 20,000 citizens '*are called upon to develop Urban Greening Plans including measures to create biodiverse and green urban forests, parks and gardens; urban farms; green roofs and walls; tree-lined streets; urban meadows; and urban hedges. They should also eliminate the use of pesticides and improve connections between green spaces. [...] To facilitate this work, the Commission will in 2021 set up an EU Urban Greening Platform, under a new 'Green City Accord*' with cities and mayors.

Even though the strategy recognized in an excellent way the crucial role of nature into cities and invite urban areas to further develop on the topic, the EU Biodiversity Strategy remains a non-binding document, potentially facing issue in its enforcement due to weak monitoring and follow up. To avoid this potential threat, the same strategy will include a monitoring and review mechanism defining a clear set of agreed indicators and will enable regular progress assessment and set out corrective action if necessary. The full implementation and enforcement of EU environmental legislation is therefore at the heart of this strategy, for which political support and financial and human resources will need to be prioritised. Also, to tap into this potential, when proposing further legislation and guidance on green public procurement (see Section 4.9), the EU Commission should integrate criteria and monitoring to boost nature-based solutions. The path towards biodiversity protection, conservation and enhancement is still long and this new EU strategy represents an up-to-date strategic document that could pave the way to greening European cities. Nevertheless, proper follow-up work of monitoring, dissemination, and dedicated allocation of funding – through the new funding programme e.g. Horizon Europe, Life programme 2021-2027 – will be necessary to ensure an effective implementation of the strategy.

3.4 WATER

Water is essential for EU citizens and the economy, but climate change and environmental degradation are putting pressure on this precious resource. At the beginning of 2000, the EU Commission developed two crucial Directives in terms of water quality (EU parliament, 2000) and floods management (EU parliament, 2007) , published respectively in 2000 and 2007. The Water Framework Directive and the Flood Directive requested Member States to develop respectively River Basin Management Plan (RBMP) and Flood Risk Management Plan (FRMP) to ensure on the one side good quality status of European water and on the other side to set up risk management plan to mitigate flood risk in European river basins and coastal areas. Now, the broad objectives of the EU water Directives – tackling water pollution, curtailing freshwater biodiversity loss, and strengthening resilience to climate change impacts – are as relevant as ever. The Water Framework Directive recognizes the value of Natural Water Retention Measures (NWRM) and supports implementation through the river basin management plans (RBMPs) and the accompanying programme of measures (PoM). Restorative NWRMs are particularly relevant e.g. restoring and recreating wetlands for water resource protection, natural bank stabilisation and re-meandering, the restoration of lakes, or floodplain restoration. NWRM are seen as Green Infrastructures applied to the water sector, as an alternative to grey infrastructure (Article 4.7) to achieve and maintain healthy water ecosystems and offer multiple benefits. In the agriculture sector, agricultural soil moisture conservation practices can be linked to agricultural NWRM. No specific link to urban areas is highlighted, except the connection with the Urban Wastewater Directive. On the other side, floods are one of the most common and most dangerous natural hazards affecting EU cities. The need to develop Flood Risk Management Plans (FRMPs) at river basins is strictly connected to the increasing risks and likely impacts of flooding in Europe due to the modification of water bodies' natural courses, the transformation of natural surfaces into hard, impervious surfaces or agricultural areas, which have a higher run-off rate, the increases in population density, floodplain development and land-use change and lately climate change impacts (Trémolet et al. 2019). While there is a long tradition for constructing engineered flood control infrastructure such as levees, retention basins, straightening or transversal barriers (EU Commission,

2018) there is an increasing interest to invest in nature-based solutions (NBS), that can reduce the frequency and/or intensity of flood, provide more resilient responses and multiple benefits and improve risk management, compared to investing in conventional methods alone (Trémolet et al. 2019). NBS can offer several co-benefits besides flood risk reduction, such as water savings, energy savings due to less cooling usage, air quality improvement, carbon sequestration and recreational and economic opportunities, co-benefits that are even bigger in urban areas. Traditionally, these co-benefits were not included in decision making processes for flood risk management (Alves et al. 2019).

The Flood Directive does not specify what kind of water retention measures are preferable. However, Natural Water Retention Measures (NWRM) are mentioned in the text and can be considered types of NBS. NWRM include (1) interception (retaining water in and on plants), (2) increased plant transpiration, (3) improved soil infiltration, (4) ponds and wetlands, and (5) reconnecting the floodplain. Also, floodplain and wetland restoration, re-allocation of dykes or re-meandering can be considered a NBS that mitigates water-related risks. These measures have the potential to reduce extreme flow discharge and thus help to level out extreme events. Positive effects can include a beneficial impact on ecological issues (i.e., nutrition retention), agriculture (irrigation) or tourism) (Hartmann et al. 2019). Several public authorities at local and regional level have made use of this opportunity and implemented NBS (e.g. relocating dikes, using floodplain forests) to cope with floods in a sustainable way, but they still represent only a small percentage of authorities. The low uptake of NBS to mitigate flood risk are determined by different factors such as traditions, insufficient awareness of the benefits, lack of experience to scale solutions up, lacking capacity to manage or carry our NBS projects, limited financial resources or the lack of evidence of the effectiveness and long-term impacts of NBS as compared to structural measures (Naumann et al 2020). Solutions to overcome these challenges entail monitoring experiments, models and decision support tools to provide a robust evidence–based evaluation of NBS. This includes real world studies, which show how to incorporate such measures into FRMPs and their likely impact on downstream urban flood risk. Such studies are needed to encourage further uptake by decision makers and land managers such as farmers (Collentine & Futter, 2018). Furthermore, there is a need to thoroughly analyse costs and benefits and potential trade-offs of NBS, which vary depending on the location of the measure (e.g., altitude, land use). In this analysis, FRMPs should also include an assessment of the potential co-benefits generated from the implementation of NBS in urban and peri-urban areas (e.g. socio-economic benefit from the recreational aspect, climate change mitigation, habitat for native species, etc.) and consider them as an added value. Even though further evidence from science should be developed and transferred to planners and practitioners, local RBMP and FRMP can already boost NBS as a powerful tool to reach the Directives targets and objectives. The recent Water Fitness Check (EU Commission, 2019c) of the Water Framework Directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive stated that nature-based solutions *offer multiple benefits in many cases, thus offering potential for all the affected legislation and policies to be implemented more efficiently*, possibly suggesting a stronger integration in the future.

3.5 COASTAL MANAGEMENT AND MARINE ENVIRONMENT

More than 40% of EU population currently live in coastal regions (EUROSTAT, 2011), that are often extremely rich socio-ecological hotspots that are becoming increasingly populated and urbanized (Jongman et al. 2012). At the same, due to GHG increasing emissions and climate change impacts, coastal areas are among the most vulnerable areas (Berry et al 2007). Green House Gases (GHGs) and related ocean acidification is extremely dangerous for the already fragile marine ecosystems and at the same time coastal communities will be strongly affected by extreme weather events (Forzieri et al., 2016) and sea-level rise (Athanasiou et al., 2020; Bosello, Nicholls, Richards, Roson, & Tol, 2012) that are expected to accelerate through the 21st Century. Even if these emissions will reduce substantially, sea-level rise will probably be significant through the 21st Century and beyond. This poses a major challenge to long-term coastal management.

According to recent research works (Gracia, Rangel-Buitrago, Oakley, & Williams, 2018; Narayan et al., 2016), ecosystem-based approaches and nature-based solutions can greatly support and enhance resilience of coastal areas and restore marine ecosystems quality and services. An ecosystem-based approach integrates ecological, economic and social objectives in one holistic approach, respecting ecological limits/carrying capacity, and balances human use and development needs with ecosystem conservation and protection needs. This is acknowledged both by the Marine Strategy Framework Directive (EU parliament, 2008) and by the proposal for a framework for maritime spatial planning and integrated coastal management(EU Commission, 2013c). Both documents focus on maintaining ecosystem integrity and functioning to ensure resilience to change and sustained delivery of ecosystem services. Maritime and coastal activities are often closely interrelated. This requires maritime spatial plans and integrated coastal management strategies to be coordinated or integrated to guarantee the sustainable use of maritime space and management of coastal areas taking account of social, economic and environmental factors. While the Marine Strategy Framework Directive requires Member States, in line with the Water Framework Directive, to achieve a good environmental status, the proposal of a wider integrated coastal management also recognized the complexity of coastal socio-ecological systems and include the idea of defining cross-sectorial policies *to foster coordinated and coherent decision-making to maximise the sustainable development*. Recognizing that well-being of populations and the economic viability of many business activities in coastal zones depend on the environmental status of these areas and of the services provided by that specific ecosystem, the Directive calls for the development of long-term integrated management tools to enhance the protection of coastal resources whilst increasing the efficiency of their use. A sectoral approach can lead to disconnected responses and decisions that could undermine each other. Nevertheless, even though socio-ecological coastal areas are recognized within the directives as crucial socio-ecological systems, the role of local authorities and communities is not explicitly mentioned in the directives, as well as the role of nature in supporting their transition towards sustainability and climate resilience. Indeed, preservation, protection and conservation of coastal ecosystem and their services is explicitly granted in the documents, but the idea of using nature and ecosystems, such as mangrove as potential solutions to coastal areas challenges is not mentioned, while largely recognized in scientific literature (Duarte, Losada, Hendriks, Mazarrasa, & Marbà, 2013). Further revision and integration of such strategies also with other relevant strategies and directives -i.e Flood Directive and Climate Adaptation Strategy - would be needed in a near future to bring coastal communities forward in their transition towards sustainability.

3.6 CLIMATE ADAPTATION AND MITIGATION

The use of nature in the context of achieving climate adaptation was first included in the EU White Paper on Adaptation (EU Commission, 2009), describing the crucial role of green infrastructure (GI) in the provision of social and economic benefits to support adaptation under extreme climatic conditions. The EU Adaptation Strategy was then adopted in 2013 to enhance the preparedness and capacity of Europe to respond to foreseen climate impacts at the local, regional, national and EU levels by scaling up climate-resilience(EU Commission, 2013a). As with the White Paper, the Strategy explicitly encourages GI implementation and the application of ecosystem-based adaptation approaches as part of a coordinated European approach to climate adaptation (Mysiak et al., 2018). Specifically, the Adaptation Strategy focuses on three key objectives; these and their linkages to NBS are:

- Promote action by Member States, encouraging and supporting the adoption of comprehensive adaptation strategies. The aim to encourage projects with demonstration and transferability potential, as well as green infrastructure and ecosystem-based approaches to adaptation is explicitly outlined.

- Promote adaptation in key vulnerable sectors (e.g. agriculture, fisheries and cohesion policy) to ensure that Europe's infrastructure is more resilient - 'Climate-proofing'. This also includes encouraging insurance against natural disasters, drawing attention to the idea of using ecosystems to buffer against weather extremes and reduce the impact of disturbances on real estate and built infrastructure (e.g. coastal ecosystems as a barrier to storm surges, permeable surfaces to protect against flooding and urban trees to mitigate heat waves)
- Support more informed decision-making by addressing gaps in knowledge about adaptation and further developing the European climate adaptation platform 'Climate-ADAPT'.
- Improve access to information on the costs, benefits, necessary conditions and successful case studies of GI and ecosystem-based approaches can only support uptake in the long-run for such approaches through increased buy-in and confidence in NBS effectiveness for adaptation.

While the Strategy only explicitly mentions one type of NBS (i.e. 'sustainable water management'), it encourages the use of ecosystem-based approaches to adaptation and deployment of green infrastructure more broadly and highlights their multiple values as "*win-win, low cost and no-regret adaptation options*" (p. 5). Green infrastructure along coastlines could further help protect against erosion and flooding, provide water retention services to mitigate floods or seasonal water scarcity, and reduce societal exposure to landslides, flooding, storms and wave surges.

The Strategy also includes eight concrete actions, which support the three overarching objectives. Action 7 is the only action to explicitly provide support for adaptation measures, aiming to "ensure more resilient infrastructure". Specifically, this action foresees the provisioning of guidance for local authorities and decision makers, civil society, private business and conservation practitioners on how to fully mobilise ecosystem-based approaches to adaptation. Despite both climate adaptation and nature-based solutions being widely advocated in the strategy, there has not yet been a systematic implementation or mainstreaming for sustainable urban development and increased climate-resilience. An answer requires the use of more standardized indicators across MS to monitor and assess the effectiveness of different green infrastructure regarding climate adaptation. While the EU Adaptation Strategy has already made noteworthy contributions to addressing these gaps, significant room remains to strengthen requirements and accompanying support for MS (e.g. in the form of guidance for local authorities and decision-makers, civil society, private businesses and conservation practitioners), foster wider cross-sectoral integration and uptake and generate critical knowledge to fill remaining gaps. Finally, the links between policy and science should be extended and strengthened within the climate adaptation strategy. Its review should consider the wealth of knowledge and data emerging from H2020-funded NBS–focused projects. Similarly, to the EU Biodiversity strategy towards 2030, stronger coordination and work would be needed in terms of strengthening monitoring, dissemination, and capacity building actions, to obtain valuable and long-lasting results.

At the same time, the EU Commission is constantly working on climate mitigation actions and the first European Climate Change Programme (ECCP) was established in 2000 to help identify the most environmentally and cost-effective policies and measures that could be taken at European level to cut greenhouse gas emissions (GHGs), according to the targets agreed in the Kyoto Protocol. In 2007, EU leaders started to set even more ambitious targets than the ones embedded in international policies and agreements and the 2020 package was a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. It sets three key targets:

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

The same targets have been made more ambitious towards 2030 when the EU commission proposed the new 2030 Climate target plan (EU Commission, 2020d):

- At least 55% cuts in greenhouse gas emissions (from 1990 levels)
- At least 55% share for renewable energy
- At least 32.5% improvement in energy efficiency

While ecosystem services and nature-based solutions are not mentioned within this package, agriculture, land use, land-use change and forestry are mentioned as relevant sectors in the GHG reduction target for 2030. The framework defined that accompanying policy measures should also build on the experiences from "greening" under the Common Agricultural Policy and ensure coherence with other Union policies. While the energy efficiency directive doesn’t include any reference to potential nature-based solutions for improving energy efficiency and buildings thermal comfort (i.e green walls and roof), the Directive does mention the crucial role of local authorities that all over Europe were already taking actions developing local Sustainable Energy plan (SEP).

The EU climate policy is currently facing a crucial moment since, with the EU Green Deal, the EU claims that it will become climate-neutral by 2050. Climate neutrality foreseen an economy model with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. Currently the transition to a just climate-neutral society is an urgent challenge and at the same time an opportunity to build a better future for all. The current proposal for a framework for achieving climate neutrality (EU Commission, 2020c) refers to the establishment of a European Climate Pact (ECP) that aims to engage citizens and communities in action for our climate and environment. Within this ECP, to be launched in the last quarter of 2020, one of the three sectors will be related with tree-planting, nature regeneration and greening of urban areas. Nevertheless, the proposal does not explicitly include the role of cities and the potential role of nature in achieving a climate neutrality and could be further reinforced in the final communication.

3.7 CIRCULAR ECONOMY

The Circular Economy (CE) concept is currently of great interest to the policy, science and practitioners' side, being also at the centre of the business and public debate. Circular economy can be viewed as a way of operationalizing the concept of sustainable development not just into the business sector, but also into cities' transition pathway (Ghisellini, Cialani, & Ulgiati, 2016).

CE promotes a more appropriate and environmentally sound use of resources requiring both a deep understanding and creative thinking of products, industrial processes and services throughout their life cycle. (Geissdoerfer, Bocken, & Hultink, 2016) argue that core aspects of CE typically include long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling. They define that the CE is "a *regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops*"

The same circular approach is now being adapted and applied also to cities, being responsible for around 70 % of global resources and of all energy produced, emit 70 % of all greenhouse gases and generate about 70 % of global waste (Parnell, 2016). Prendeville, Cherim, and Bocken 2018 define a circular city as "*a city that practices circular economy principles to close resource loops, in partnership with the city's stakeholders (citizens, community, business and knowledge stakeholders), to realize its vision of a future-proof city*".

The circular cities concept is well recognized at international level with an increasing number of networks and initiatives raising (Ellen Mac Arthur, C40) and since 2014 is increasingly gaining attention also in European policies with the launch of the EU action plan for the circular economy (EU Commission, 2014). The CE package mostly focused on stimulate Europe's transition towards a circular economy, with measures covering production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste. Under the umbrella of the so-called "closing the loop" concept the EU action plan mostly focused on greater recycling and re-use, and it does not include any reference to a broader understanding of circular economy and to its potential implementation into cities. Nevertheless, many European cities started to implement the circular city concept in their urban areas through various initiatives, i.e. temporary use or permanent reuse of land, buildings and properties, phytoremediation to restore contaminated soil; waste-water treatment and reuse to produce fertilizer for local food crops. Through the Pact of Amsterdam, 2016, and the so so-called Urban Agenda process (see par 3.10) one of the partnerships was called to provide recommendation to the EU Commission on better knowledge, funding, and regulation, cities would need to work towards circular future. The new Circular Economy Action Plan (EU Commission, 2020a) is embedded within the EU Green Deal and focuses on sustainable use of resources. In terms of natural resources and capital preservation, water and nutrients are well embedded within the new action plan proposal, encouraging water reuse in agriculture and proposing the development of an Integrated Nutrient Management Plan, with a view to ensuring more sustainable application of nutrients and stimulating the markets for recovered nutrients. Nevertheless, the new Plan still overlooks at land as one of the most crucial and currently at risk non-renewable natural resources. Although in the EU policy the processes avoiding new land take are generally seen as one of the benefits of circular economy, land itself is rarely viewed as a resource on its own. The main reason might be that it is not easy to include land into consumption and production loops and, even more importantly, that EU has less direct influence on urban development and planning issues than on more concrete environmental aspects.

As stated by Sustainable and circular reuse of spaces and buildings handbook(Urban Agenda Partnership, 2019), these strategic statements are, however, much weaker than the EU compulsory directives adopted in the environmental field (regarding waste, wastewater, water, etc.). In this regard it is the national, regional and local administrations which have to make stronger, binding steps towards the re-use of land and buildings, underpinned by binding legislations. Local municipalities can potentially play an important role to this respect. With strong competences on development and planning issues, municipalities can and should include urban circular re-use of abandoned or underused properties into their urban development policies and strategies and should step up as initiators for corresponding regional and national policies and legislations. This process can be boosted by the support provided by already set and newly proposed networks and initiatives to provide key assistance to cities such as the European Urban Initiative, the Intelligent Cities Challenge Initiative, the Circular Cities and Regions Initiative and the Green City Accord. The Circular Cities and Regions Initiative (CCRI) is part of the new Circular Economy Action Plan and will focus on the implementation of circular solutions at local and regional scale. The CCRI has been launched in October 2020 and it will provide a contribution to the implementation of the European Green Deal and the EU Bioeconomy Strategy, explicitly recognizing the crucial role of cities in this transition, pushing spatial planning to intervene in markets to provide space, long-term, for low-value, circular activities.

3.8 ENVIRONMENTAL IMPACT

The topic of land-use and land change is not only relevant for circular economy related policies and actions but plays a crucial role also within environmental assessment related strategies and directives. Since 1985, with the first approval of the Environmental Impact Assessment Directive (European Council, 1985), the EU requires projects that could have significant adverse effects on the environment to provide information on measures envisaged to avoid prevent or reduce such adverse impacts . The EU Directive for Environmental Impact Assessment (EIA) put in place the concept of environmental assessments on a European scale, with the aim to assess public and private projects with significant negative effects on the environment throughout Europe.

The development of environmental assessment requirements for local, regional and national plans and programs is based on this initial legislative framework but has since transitioned away from the EIA approach (Noble & Nwanekezie, 2017). As such, the EU Strategic Environmental Assessment Directive entered into force in 2001 (EU parliament, 2001), requiring authorities to undertake an environmental assessment of public sector plans and programmes with likely effects on the environment. The objective of SEA Directive is to provide a high level of protection for the environment. This is to be achieved by increasing the integration of environmental considerations in the preparation and adoption of plans and programmes, with a view to promoting sustainable development. It sets out standard procedures for undertaking such strategic-level environmental assessments. The entering into force of the SEA directive introduced not just the idea of evaluating the sustainability of policies and plans that could negatively impact the environment, but also proposed the comparison of diverse alternatives and more sustainable scenario for urban and territorial development. In this regard, land use and land change in urban and peri-urban areas remain among the most discussed issues at planning level. The application of Strategic Environmental Assessments (SEA) has the potential to address these negative impacts by enabling strategic thinking for the integration of environmental factors into decision-making processes, supporting the transition towards environmentally sustainable economic growth in Europe (Noble & Nwanekezie, 2017). The ESPON project "Green Infrastructure: Enhancing biodiversity and ecosystem services for territorial development" (GRETA) identified linkages between green infrastructure and the SEA Directive. While nature-based solutions are not directly mentioned within the Directive, they are implied as a benchmark for the sustainable alternatives to planning that are required under Article 5. In order to effectively integrate nature into policies, plans and programs, nature-based solutions are apparent to replace grey designs (Kabisch, Strohbach, Haase, & Kronenberg, 2016). Nature-based solutions can have a wide range of co-benefits that have the potential to assist in navigating a plethora of environmental issues, as well as increase resilience and enable a sustainable use of resources (Wendling, Huovila, zu Castell-Rüdenhausen, Hukkalainen, & Airaksinen, 2018). However, as is the case for multiple concepts, such as green infrastructure and ecosystem services, Strategic Environmental Assessment and Nature-Based Solutions (NBS) have until now not been widely connected. Applying nature-based solutions within the SEA context has the potential to close gaps between economic ambition and sustainable long-term environmental goals in knowledge-based decision making. In general, the SEA Directive is limited to requiring the undertaking of an assessment and determination of alternatives but does not explicitly introduce sustainable solutions such as NBS or require their application in favour of grey solutions. Nevertheless, the criteria to determine environmental impact clearly favours greener solutions. Though NBS were not explicitly mentioned in the SEA Directive's text, one of the main takeaways is that the criteria to determine whether a project, plan or policy will negatively impact the environment would ultimately always favour greener solutions over traditional 'grey' infrastructure. Requiring all applicants to review 'reasonable alternatives' (Article 5) can be viewed as implicitly encouraging more natural or environmental-friendly solutions, encouraging contractors and planners to maximise win-win solutions to meet development needs while retaining ecological status. Without the enhanced knowledge basis that SEA requires, NBS would perhaps not be discovered as solutions to begin with. Thus, even though NBS are not actively considered for SEA, indirect influence and the potential for enhancing linkages is high, as discussed below. The nature of the SEA Directive requires an integrated assessment of plans and programs and their effect on the environment, linking to the general EU environmental legislative framework. The Water Framework Directive, for example, established the key procedural requirement of river basin management plans, thus the link between WFD and SEA Directive require SEA application during River Basin Management Plan preparation . Thus, as the SEA Directive supports the implementation of numerous EU Directives and Strategies (i.e. Nitrates, Waste, Noise, and Flood Risk) that have various indirect and direct links with NBS, there remains potential for strengthening these linkages in the future. SEA would benefit from an integrated analysis of co-benefits for nature-based solutions, ranging from cultural ecosystem services such as recreational opportunities to climate mitigation, as these can be considered as the strongest motivations for promoting NBS (Geneletti & Zardo, 2016; Rozas-Vásquez et al., 2018). If the SEA Directive were not only to ensure integration of environmental assessments across policies, plans and strategies, but to explicitly rank opportunities for nature-based solutions above alternative solutions on the basis of higher co-benefits across determining factors (i.e. human health, biodiversity, material assets (SEA Directive, Article 3), this would have a great effect across the European legislative framework. The final Action plan of the Partnership on Sustainable Use of Land and Nature-based Solutions has addressed that a reference to ‘land take’ is missing in SEAs. This creates an incentive for policies and programmes to overlook the negative territorial and environmental impacts. The missing consideration of land take could prove a valuable entry point for NBS. The Directive is intended to contribute to the integration of environmental considerations in the preparation and adoption of plans and programmes (including at the local level) and to promote sustainable development. For nature-based solutions to be effectively considered for SEA, it needs to be ensured that practitioners and policy makers that apply SEA be sufficiently guided in terms of NBS definition, good practice examples and how to include it in processes (Honrado et al., 2013). As already mentioned for the Flood Directive, the assessment of the co-benefits provided by alternative ecosystem and nature-based approaches and solutions could largely favour such approaches against traditional plans and solutions.

3.9 GREEN PUBLIC PROCUREMENT

Public Procurements may be an important driver towards environmentally friendly procurement. Indeed, the public sector can influence green procurement both by designing suitable policies and by leveraging “green” markets through the significant dimension of public purchases. The basic concept of Green Public Procurement (GPP) relies on integrating environmental criteria for public products and services procurement. GPP is defined in the European Commission's Communication as “a process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured." (EU Commission, 2008). The use of the voluntary EU GPP criteria for public space maintenance has the potential to deploy nature to considerably reduce environmental impacts in the sector and can help stimulate demand for more sustainable goods and services (e.g. eco-innovations). Among the 20 GPP criteria for specific sectors at least four of them already mentioned NBS and ES and could be relevant to boost nature-based innovation within urban areas:

- Criteria for Office Building Design, Construction and Management – 2016: The integration of nature-based solutions, such as green roofs and walls, habitats in courtyards and patios, Sustainable Urban Drainage Systems (SUDS) and street trees can have multiple advantages (in addition to supporting biodiversity) and is well acknowledged in the document.
- Criteria for Public Space Maintenance – 2019 Specification about gardening products and services could be further integrated in terms of nature-based solutions.
- Criteria for Road Design, Construction and Maintenance – 2016. There is a well-documented integration of NBS in the document covering: i) specification of approaches to lower noise emissions (including nature-based solutions) during construction, use and maintenance phase; ii) introducing water pollution control components and stormwater retention capacity components, including soft engineered solutions (e.g. nature-based solutions) in the drainage system; iii) including potential for habitat creation notably to reduce runoff into storm sewers and the overall amount of water entering local storm sewers or surface waters thereby significantly reducing flooding-related damages.
- Criteria for waste-water infrastructure – 2013. There is no specific reference to nature-based solutions or innovations in the document even though phytoremediation could be considered to integrate and improve the performance of existing wastewater treatment (Schröder et al., 2007). On this topic more knowledge is needed to support more ambitious criteria in this sector.

Three out of four GPP criteria analysed explicitly mentioned and well integrate the concept of NBSs. Also, as explicitly mentioned in the EU Biodiversity Strategy to 2030, the Commission will further work on Public procurement criteria to boost ES and NBS.

3.10 OTHER RELEVANT INITIATIVES

As already mentioned in previous paragraphs covering EU policies, the European Union is currently working towards urban sustainability and nature-based solutions also on several related initiatives and funding programme. To boost NBS implementation within EU cities and to assess their effectiveness in relation with different societal challenges, the EU Commission included NBSs, and the related ES services they provide, as one of the main topics within the H2020 research and innovation programme and demonstration projects are currently taking place in several European cities. At the same time, in May 2016, with the definition of the Pact of Amsterdam, the EU launched the Urban Agenda for the EU process which presents strategic objectives related to urban issues while being legally non-binding (Purkarthofer, 2019). The Urban Agenda for the EU is a new multi-level working method promoting cooperation between Member States, cities, the European Commission and other stakeholders in order to stimulate growth, liveability and innovation in the cities of Europe. The Urban agenda can be considered a new soft territorial governance model supported by the European Union (Purkarthofer, 2019). Based on the principles of subsidiarity and proportionality, the Urban Agenda focuses on the three pillars of EU policy making and implementation Better regulation, Better funding and Better knowledge (Pact of Amsterdam, 2016).

So far 16 partnerships have been constituted to develop and implement action plans to successfully tackle challenges of cities and to contribute to smart, sustainable and inclusive growth. Among those partnerships at least 4 of them - Air Quality, Circular Economy, Climate Adaptation and Sustainable Use of Land and Nature-Based Solutions – have included NBS and ecosystem services as crucial element of sustainable urban transition. The outcomes of such partnerships have been integrated in previous paragraphs for relevant policies. Specifically, the partnership dedicated to Sustainable use of land and nature-based solutions focused on urban sprawl, development of brownfields and renaturing/ greening urban areas. Following the steps given by the Urban Agenda, the partnership, coordinated by the Municipality of Bologna and the Ministry of economic development in Poland, identified the main barriers and challenges related with sustainable land use and NBS and included those in an orientation paper published in December 2017 (Urban Agenda Partnership, 2017). The partnership, through a bottom-up and participatory process, which deeply involved all the members of the partnership and some external stakeholders in face to face and remote meetings, agreed that finding the balance between urban compactness on the one hand, and achieving high standards of quality of life in a healthy urban environment on the other one, is one of the major challenges for Europe's urban areas. Building on this consideration, the partnership analysed the state of the art in terms of funding opportunities, knowledge gap and current regulation. The developed action plan aims "to ensure the efficient and sustainable use of land and other natural resources to help create compact, liveable and inclusive European cities". It is underpinned by two objectives: 1) to promote the liveable compactness city model and 2) to mainstream and promote NBS as a tool to build sustainable, resilient and liveable urban spaces. The Partnership acknowledges the close relationship between sustainable land use and NBS, focusing on the sustainable use of land and nature a solution to current societal challenges. It promotes compact city development, reducing urban sprawl and minimising land-take using e.g. NBS. It foresees specific NBSs actions including, for example, Indicators of Land Take, Better Regulation to Boost NBS at EU and Local Level, Better Financing on NBS, or Awareness Raising on NBS and Urban Sprawl.

3.10.1 RESEARCH AND INNOVATION PROJECT ON ES AND NBS

Research and innovation are among the priorities of European Union that through dedicated funding programmes support and encourage cooperation between research teams across countries and disciplines. From the beginning of the 1980s, the European Commission proposed the framework programme (FP) for research as a strategic tool to manage the adoption of research programmes in a coherent way. From the first framework programme (FP1) adopted in 1983 thousands of cross-border and multidisciplinary research projects have been funded supporting advancement in science and informing better decision and policy making. At the end of 2020, the 8th framework programme – Horizon2020 – will come to an end and the new programme, the so-called Horizon Europe, will guide research and innovation up to 2028. Research and innovation funds are not limited to research Framework programmes (FPs), but vary across a span of other relevant funding programme (LIFE, ClimateKIC, COSME, etc.) Nevertheless, in the scope of this work, a filtered research has been implemented within the CORDIS database looking for research projects related to ecosystem services and nature-based solutions over the time within EU framework programmes.

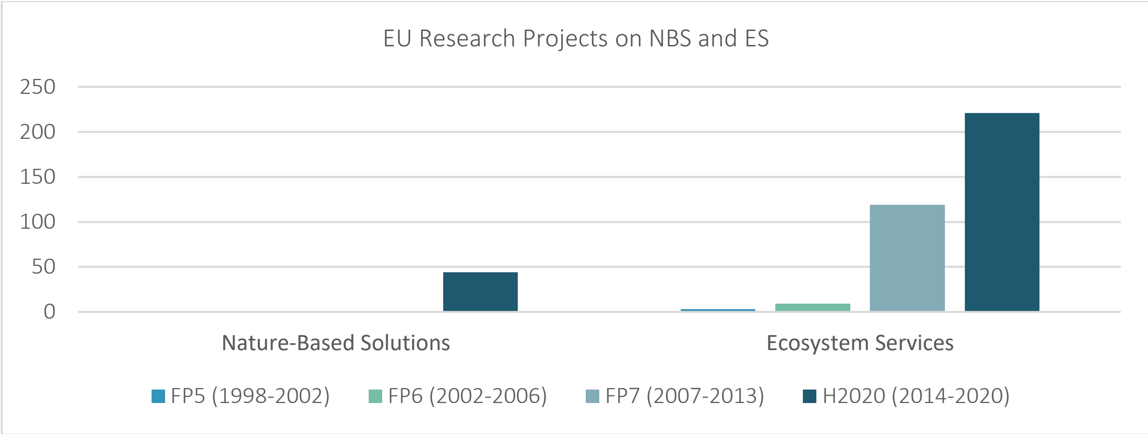


Figure 3-1 NBS and ES funded projects in EU FPs since 1998

Fig.3-1 confirms the growing trend of research in the topic and the emergence of nature-based solutions later in time, just in the last H2020 funding programme. Interestingly, most of the recently funded projects within H2020 on NBS relate with sustainable and smart urbanization and aim at providing evidence and demonstrating the multiple benefits of NBS implementation in cities. The EU Commission mapped the most recently funded projects related with NBS and ES in cities that are expected in the following months to provide new scientific evidence, business and governance models and monitoring scheme to further boost and mainstream the uptake of NBS over Europe. The list of such projects is presented in Figure 3-2.

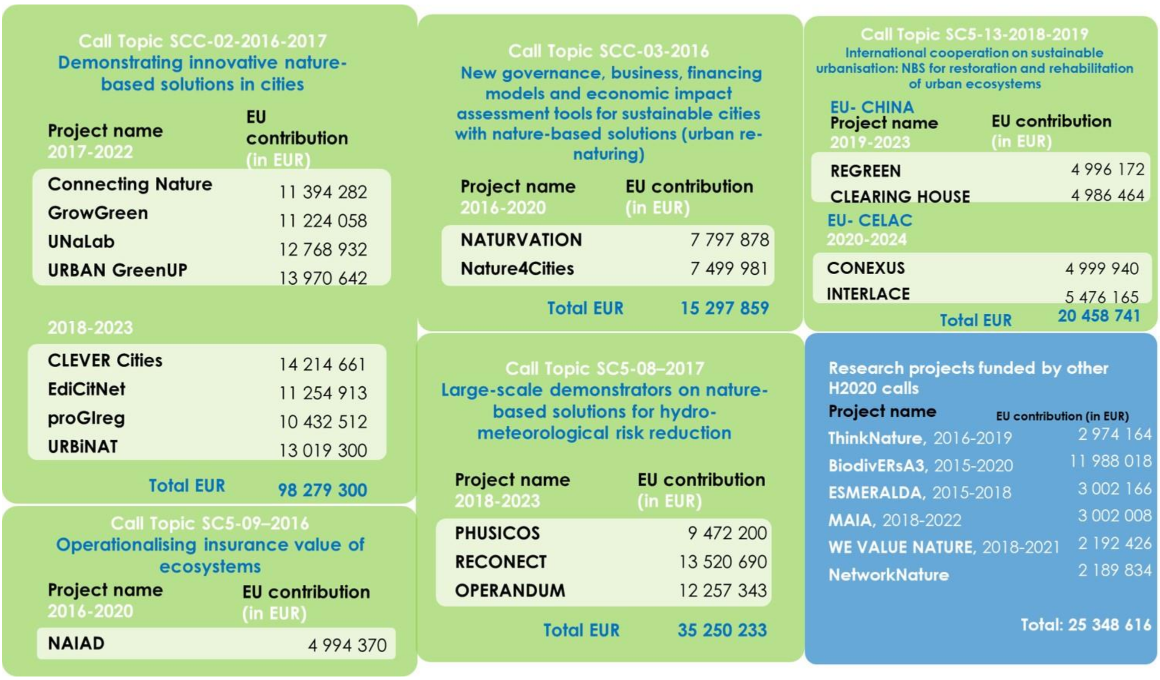


Figure 3-2 H2020 funded projects on NBS in urban areas

3.11 CONCLUSIONS

As previously mentioned, since 1973 EU environmental policies started to become one of the most significant areas of EU intervention. The policies related to environmental issues have developed in very different sectors and, in the context of this work, a selection of such sectors have been made based on their relevance to natural and urban environment. Specifically, policies related with water, environmental assessment, coastal and marine areas, biodiversity, climate change, circular economy and public procurement have been analysed. Also, strategic documents related to environment as an overarching issue, such as the Environmental Action Programme and the EU Green Deal, have been take into consideration. For each sector, the main policies have been analysed looking for:

- General or specific reference to the role of nature in the achievement of defined targets (specific ecosystem services and nature-based solutions references);
- General or specific reference to the urban environment and its role in the achievement of defined targets.

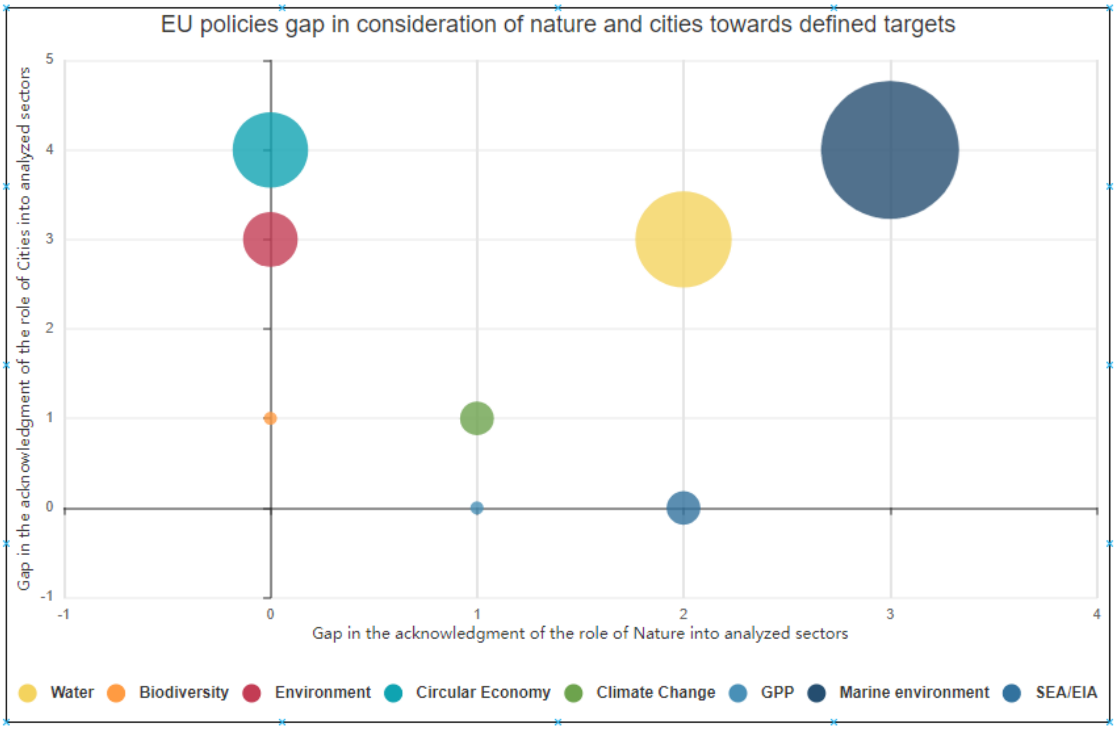


Figure 3-3 Gaps of EU policies in integrating natural and urban environment.

According to the analysis summarized in Annex I and in the previous paragraphs, the different sectors have been positioned in Fig 3-3 according to current gaps in considering natural and urban environment within their policies.

The marine environment related policies present, according to the performed analysis, the highest gap in considering both the urban and natural environment. While costal floods and climate adaptation measures for coastal communities are included also in the Flood Directive and the Climate Adaptation Strategies, neither the role of nature-based solutions (i.e mangrove) or the role of coastal urban areas or communities is properly acknowledged and recognised in the document. Also, the water sector, encompassing two crucial environmental directive, i.e the Water and the Flood Directive, could be further improved in terms of both natural and urban environment consideration. The recent Water fitness check, considering both Directives, claims for a further integration of ES and NBS in the documents. Nevertheless, a more ambitious transition towards such solutions is needed, claiming local authorities for considering and assessing NBS co-benefits, in all their projects and plans, taking in consideration, also in light of the current COVID-19 pandemic, health and wellbeing generated advantages.

On the other side, both circular economy and overarching environmental programmes very well rooted natural environment in their policy documents. Nevertheless, the role of urban environment towards a sustainable transition is neglected. Even though dedicated initiatives and networks have been set in the last decade, better regulation would be needed to strongly support circular transition, also related with better use of land. In this sense, even though a European Directive on soil and land use would be desirable, it could be relevant to better integrate land use and land change issue in current circular economy and environmental assessment policies and directives. Scenario development and alternatives' evaluation in urban and territorial planning and decision-making process should include land use and change among their priority assessment criteria, embedding this procedure into business-as-usual local administration processes. This could pass through a revision of the current SEA, with clear land take indicators and further ecosystem-based approaches developed. Last, climate change and biodiversity policies have a wide understanding and very good integration of both natural and urban environment. Nevertheless, climate adaptation and biodiversity objectives are both incorporated in thematic strategies, thus being non-binding policy documents. The potential weaknesses of such instruments could be overcome if a substantial monitoring and follow up process is developed and if the implementation of such strategies would bound the access to specific funding programme and initiatives, pushing cities and national government to more seriously uptake such instruments.

The evolution of the EU environmental policies well-reflect the overall discourse around environment and sustainability. Starting with sectorial policies, the European Union is gradually moving sustainability issue at the centre of its own development and growth policy. With the development of the first circular economy action plan (2015), the EU Commission started to develop the idea that a just transition towards a sustainable future should pass through a new economic and development model, cross-sectorial and multidisciplinary. Evidence and awareness of the potential of natural ecosystems, green infrastructure, and nature-based solutions to support progress towards urban sustainability continues to grow. Since urban matters are not directly under the responsibility of the European Union, NBS and related concepts such as ecosystem-based adaptation, green infrastructure, and natural water retention measures are being increasingly integrated in a range of environmental, climate and biodiversity policies at EU level. Most of these policies have a direct impact on cities that should either comply with them or integrate their recommendations into their local policies, strategies, and plans.

As mentioned in previous chapter, within the international context, also the European Union is now at a crossroads; the current pandemic is posing huge challenges, but also offers a great opportunity to set up a recovery plan based on socio-economic, environmental and climate justice. The new EU Green Deal is a crucial step of the EU recovery plan and set an important first step towards a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy. Greening the other policies sectors, including NBS and ES approaches, and recognizing the crucial role of urban areas towards sustainable and inclusive growth, would be crucial to ensure not just a competitive economy but also an inclusive and sustainable transition of the EU, maintaining and enhancing European citizens' health, wellbeing and quality of life.

LIST OF REFERENCE

Athanasiou, P., van Dongeren, A., Giardino, A., Vousdoukas, M. I., Ranasinghe, R., & Kwadijk, J. (2020). Uncertainties in projections of sandy beach erosion due to sea level rise: an analysis at the European scale. *Scientific Reports*, *10*(1), 1–14. https://doi.org/10.1038/s41598-020-68576-0

Berry, P.M., Jones, A.P., Nicholls, R.J. and Vos, C.C. (eds.) 2007. Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate - BRANCH project Final Report, Natural England, UK.

Bosello, F., Nicholls, R. J., Richards, J., Roson, R., & Tol, R. S. J. (2012). Economic impacts of climate change in Europe: Sea-level rise. *Climatic Change*, *112*(1), 63–81. https://doi.org/10.1007/s10584-011-0340-1

Bouwma, I., Schleyer, C., Primmer, E., Winkler, K. J., Berry, P., Young, J., … Vadineanu, A. (2017). Adoption of the ecosystem services concept in EU policies. *Ecosystem Services*. https://doi.org/10.1016/J.ECOSER.2017.02.014

Claeys, G., Tagliapietra, S., & Zachmann, G. (2019). How to make the European Green Deal work. *Bruegel Policy Contribution*, (No 14), 21.

Collentine, D., & Futter, M. N. (2018). Realising the potential of natural water retention measures in catchment flood management: trade-offs and matching interests. *Journal of Flood Risk Management*, *11*(1), 76–84. https://doi.org/10.1111/jfr3.12269

Corlett, R. T., Primack, richard B., Devictor, V., Maas, B., Goswami, Varun, R., Bates, A., … Roth, R. (2020). Editorial - Impacts of the coronavirus pandemic on biodiversity conservation. *Biological Conservation*, *246*(January).

de la Fuente, B., Mateo-Sánchez, M. C., Rodríguez, G., Gastón, A., Pérez de Ayala, R., Colomina-Pérez, D., … Saura, S. (2018). Natura 2000 sites, public forests and riparian corridors: The connectivity backbone of forest green infrastructure. *Land Use Policy*, *75*(April), 429–441. https://doi.org/10.1016/j.landusepol.2018.04.002

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I., & Marbà, N. (2013). The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change*, *3*(11), 961–968. https://doi.org/10.1038/nclimate1970

ECC. (1957). European Economic Community- Traité Instituant La Communauté Économique Européenne. *Annuaire Européen / European Yearbook*, (150), 412–639. https://doi.org/10.1007/978-94-015-3885-5_23

EEA. (2019). European environment Agency. The European environment-state and outlook 2020. Knowledge for transition to a sustainable Europe. In *Luxembourg: Publications Office of the European Union, 2019*. https://doi.org/10.15196/TS600305

EU Commission. (2008). *P*ublic procurement for a better environment.

EU Commission. (2009). WHITE PAPER Adapting to climate change: Towards a European framework for action.

EU Commission. (2013a). An EU Strategy on adaptation to climate change. https://doi.org/10.1017/CBO9781107415324.004

EU Commission. (2013b). Green Infrastructure (GI) — Enhancing Europe's Natural Capital.

EU Commission. (2013c). Proposal *for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for maritime spatial planning and integrated coastal management*.

EU Commission. (2014). Communication from the Commission - Towards a circular economy: A zero waste programme for Europe. *European Commission*.

EU Commission. (2018). *COMMISSION STAFF WORKING DOCUMENT Adaptation preparedness scoreboard Country fiches Accompanying the document REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the EU Strategy on adaptation to climate change*.

EU Commission (2019a) EU Guidance on integrating ecosystem and their services into decision making: Commission Staff Working Document

EU Commission (2019b) Review of progress on implementation of the EU green infrastracture strategy: Report from the Commission to the Europan parliament, the council, the European Economic and Social Comitteee and the Committee of Regions

EU Commission. (2019c). Fitness Check Water Framework directive, Groundwater Directive, Environmental Quality Standards Directive and Floods Directive. *NASPA Journal*, Vol. 42, p. 1. https://doi.org/10.1017/CBO9781107415324.004

EU Commission. (2020). Natura 200 network: Retrieved from https://ec.europa.eu/environment/nature/natura2000/index_en.htm

EU Commission. (2020a). A new Circular Economy Action Plan For a cleaner and more competitive Europe EN. https://doi.org/10.7312/columbia/9780231167352.003.0015

EU Commission. (2020b). EU Biodiversity Strategy for 2030. COM(2020) 380 Final. https://doi.org/10.1017/CBO9781107415324.004

EU Commission. (2020c). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law). COM(2020) 80 Final, Vol. 0036, p. 25. https://doi.org/10.1017/CBO9781107415324.004

EU Commission. (2020d). Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people. Journal of Chemical Information and Modeling.

EU Council. (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (OJ L 206 22.07.1992 p. 7). https://doi.org/10.1017/cbo9780511610851.039

EU Council. (2019). The 8th Environment Action Programme - Turning the trends together. Journal of Chemical Information and Modeling, Vol. 2019, pp. 1–10. https://doi.org/10.1017/CBO9781107415324.004

EU parliament. (2000). Water Framework Directive 2000/60/EC. DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy. https://doi.org/2004R0726 - v.7 of 05.06.2013

EU parliament. (2001). Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (OJ L 197 21.07.2001 p. 30). https://doi.org/10.1017/cbo9780511610851.021

EU parliament. (2007). DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF

THE COUNCIL of 23 October 2007 on the assessment and management of flood risks.
EU parliament. (2008). DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

EU parliament. (2013). Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 "Living well, within the limits of our planet." Official Journal of the European Union. https://doi.org/10.2779/57220

European Council. (1985). Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment 85/33 7/EEC. (L), 220–234. https://doi.org/10.1680/ea.26124.bm01

Eurostat. (2011). Coastal regions population statistics retrieved fromhttps://ec.europa.eu/eurostat/statistics-explained/index.php/. Last access 23 December 2020

Forzieri, G., Feyen, L., Russo, S., Vousdoukas, M., Alfieri, L., Outten, S., … Cid, A. (2016). Multi-hazard assessment in Europe under climate change. Climatic Change, 137(1–2), 105–119. https://doi.org/10.1007/s10584-016-1661-x

Geissdoerfer, M., Bocken, N. M. P., & Hultink, E. J. (2016). Design thinking to enhance the sustainable business modelling process – A workshop based on a value mapping process. Journal of Cleaner Production, 135, 1218–1232. https://doi.org/10.1016/j.jclepro.2016.07.020

Geneletti, D., & Zardo, L. (2016). Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. Land Use Policy, 50, 38–47. https://doi.org/10.1016/J.LANDUSEPOL.2015.09.003

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner Production, 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Gracia, A., Rangel-Buitrago, N., Oakley, J. A., & Williams, A. T. (2018). Use of ecosystems in coastal erosion management. Ocean and Coastal Management, 156, 277–289. https://doi.org/10.1016/j.ocecoaman.2017.07.009

Hartmann T., Slavíková L., McCarthy S. (2019) Nature-Based Solutions in Flood Risk Management. In: Hartmann T., Slavíková L., McCarthy S. (eds) Nature-Based Flood Risk Management on Private Land. Springer, Cham. https://doi.org/10.1007/978-3-030-23842-1_1

Holzinger, K., & Sommerer, T. (2014). EU Environmental Policy: Greening the World? In EU Policies in a Global Perspective: Shaping or Taking International Regimes? (pp. 111–129). https://doi.org/10.4324/9781315867410

Honrado, J. P., Vieira, C., Soares, C., Monteiro, M. B., Marcos, B., Pereira, H. M., & Partidário, M. R. (2013). Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. Environmental Impact Assessment Review, 40(1), 14–24. https://doi.org/10.1016/j.eiar.2012.12.002

Kabisch, N., Strohbach, M., Haase, D., & Kronenberg, J. (2016). Urban green space availability in European cities. Ecological Indicators, 70, 586–596. https://doi.org/10.1016/j.ecolind.2016.02.029

Mysiak, J., Castellari, S., Kurnik, B., Swart, R., Pringle, P., Schwarze, R., … Van Der Linden, P. (2018). Brief communication: Strengthening coherence between climate change adaptation and disaster risk reduction. Natural Hazards and Earth System Sciences, 18(11), 3137–3143. https://doi.org/10.5194/nhess-18-3137-2018

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., Van Wesenbeeck, B., Pontee, N., … Burks-Copes, K. A. (2016). The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLoS ONE. https://doi.org/10.1371/journal.pone.0154735

Naumann, S., Davis, M. and Röschel, L., de Luca, C., Conticelli E. (2020). Sustainable Use of Land and Nature-Based Solutions Partnership Better regulation to boost NBS at European, national and local level (ACTION N6)

Nicholls, R. J., & Klein, R. J. T. (2005). Climate change and coastal management on Europe's coast. Managing European Coasts, 199–226. https://doi.org/10.1007/3-540-27150-3_11

Noble, B., & Nwanekezie, K. (2017). Conceptualizing strategic environmental assessment: Principles, approaches and research directions. Environmental Impact Assessment Review, 62, 165–173. https://doi.org/10.1016/j.eiar.2016.03.005

Pact of Amsterdam. (2016). Pact of Amsterdam - Urban agenda for the EU.

Parnell, S. (2016). Defining a Global Urban Development Agenda. World Development, 78, 529–540. https://doi.org/10.1016/j.worlddev.2015.10.028

Prendeville, S., Cherim, E., & Bocken, N. (2018). Circular Cities: Mapping Six Cities in Transition. Environmental Innovation and Societal Transitions, 26, 171–194. https://doi.org/10.1016/j.eist.2017.03.002

Purkarthofer, E. (2019). Investigating the partnership approach in the EU Urban Agenda from the perspective of soft planning. European Planning Studies, 27(1), 86–105. https://doi.org/10.1080/09654313.2018.1527294

Rozas-Vásquez, D., Fürst, C., Geneletti, D., & Almendra, O. (2018). Integration of ecosystem services in strategic environmental assessment across spatial planning scales. Land Use Policy, 71, 303–310. https://doi.org/10.1016/j.landusepol.2017.12.015

Schröder, P., Navarro-Aviñó, J., Azaizeh, H., Goldhirsh, A. G., DiGregorio, S., Komives, T., … Wissing, F. (2007). Using phytoremediation technologies to upgrade waste water treatment in Europe. Environmental Science and Pollution Research, 14(7), 490–497. https://doi.org/10.1065/espr2006.12.373

Trémolet S. et al. (2019). Investing in Nature for Europe Water Security. The Nature Conservancy, Ecologic Institute and ICLEI. London, United Kingdom

Urban Agenda Partnership. (2017). Urban Agenda for the EU Orientation paper Sustainable Use of Land and Nature-Based Solutions.

Urban Agenda Partnership. (2019). Sustainable and circular re-use of spaces & buildings HANDBOOK.

Wendling, L. A., Huovila, A., zu Castell-Rüdenhausen, M., Hukkalainen, M., & Airaksinen, M. (2018). Benchmarking nature-based solution and smart city assessment schemes against the sustainable development goal indicator framework. Frontiers in Environmental Science, 6(JUL), 1–18. https://doi.org/10.3389/fenvs.2018.00069

4 AN ECOSYSTEM SERVICES-BASED APPROACH FOR PLANNING URBAN SUSTAINABILITY AND RESILIENCE

ABSTRACT

Over the past two decades, significant progress has been made to identify ways in which ecosystems benefit people and on the feedbacks between management actions and their impacts on single and bundles of ecosystem services. Nevertheless, the transition from traditional urban planning to an ecosystem-based planning approach, sometimes called ecological planning is still far from being systematically integrated into cities' plans and strategies. The first section of this chapter will illustrate more in depth the three most relevant concepts for planning urban sustainability and resilience: Ecosystem Services, Green and Blue infrastructure and Nature Based Solutions and its relationship with sustainability and resilience providing the conceptual overview that will be used at the base of our methodological and conceptual approach. Then, departing from the introduction of the ES cascade model, this chapter will propose a conceptual and methodological approach, that will be further tested in Chapter 5, 6 and 7, to better inform policy making and give the proper value to ES within urban context. Specifically, we will highlight the relationships between ecosystem structures (supply), functions (capacity), services and the benefits (flow) that people (demand) gain from ecosystems, which are finally valued either in monetary or nonmonetary dimensions. Last, since planning approaches should not just look at the current situation, but should aim at ensuring Ecosystem Services resilience over time, the second section of this chapter will present the conceptual and methodological framework developed within this work to support a wider understanding relevance of policy making into socio-ecological systems.

4.1 NATURE IN THE CITY: URBAN NATURE RELATED CONCEPTS AND DEFINITIONS

Approaches and concepts nurturing interdisciplinary knowledge on urban nature have evolved over recent decades and adopted a series of similar, but slightly different, concepts and vocabulary. With Urban Nature hereafter we intend all natural or semi-natural ecosystems (i.e natural and man-made ecosystems with natural features) that we can find within the city boundaries.

The origin of the concept of greenway is commonly attributed to Frederick Law Olmsted, that first present the project of the new Central Park of New York (1858) (Fig. 4-1), with the explicit scope of "bring back a bit of nature" in the city. Olmsted designed "a simply broad, open space of clean greensward, with sufficient play of surface and sufficient number of trees about to supply a variety of light and shade. This we want as a central feature. We want depth of wood enough about it not only for comfort in hot weather, but to completely shut out the city from our landscape. These are the distinguishing elements of what is properly called a park [...] The park should, as far as possible, complement the town." (Olmsted, 1870).

Figure 4-1 "Greensward", Olmsted and Vaux general plan for New York Central Park, 1858

Also in Europe, from early 19th century, the need of getting people closer to natural open space became central in the London Plan of Loudon (1829) (Fig. 4-2) stating that '*there could never be an inhabitant who would be farther than half a mile from an open airy situation, in which he was free to walk and ride, and in which he could find every mode of amusement, recreation, entertainment, and instruction*'.

Figure 4-2 London Plan, Loudon, 1829

In the same lines, at the end of the 19th century, Howard firstly developed the concept of the Garden City largely developed in the book "The garden cities of tomorrow" (Howard, 1902) (Fig. 4-3), that describes healthier cities where the city lives in closer contact with nature.

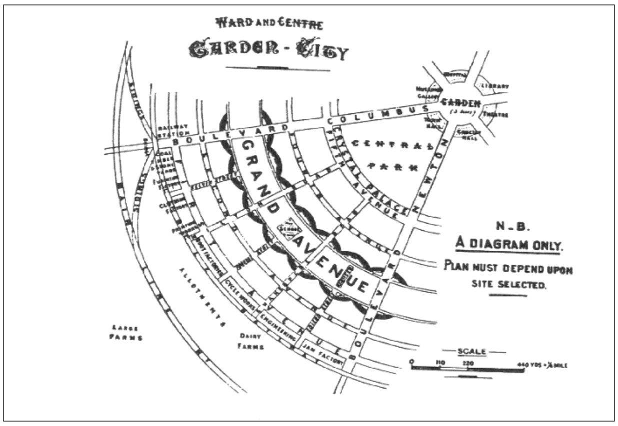


Figure 4-3 Garden City Howard 1892

Then, as from the mid of the 20th century, starting from the concepts of Greenbelts (Mumford, 1961), the idea of including and/or increasing natural features in the city, acknowledging the recreational role of green areas and nature within urban settlements, spread around the Northern Area of the Globe. In the late 90s the idea of greenways (Kühn, 2003) and ecological and wildlife corridors (Soulé, 1991) that cross the city to preserve habitat and facilitate slow mobility raised in North America and

European countries. The main objectives of such new infrastructures referred to the attempt of containing city dimension and fighting urban sprawl, to the need of improving recreational and mobility opportunities for citizen (European Greenways Association, 2000) and to face habitat fragmentation providing green and safe spaces linking habitat patches (Soulé, 1991). From the beginning of 2000s various concepts have been evolving to refer to urban nature and its role within urban settlements, and the scientific debates around those raised incrementally (Chatzimentor, et al., 2020; Escobedo et al. 2019). The need of finding new solutions to urban challenges and the raising issues concerning pollution, ecosystem degradations, and city dwellers' quality of life turned the attention from ornamental and mere recreational greening functions towards more functional and sustainable urban ecosystems. The idea of finding solutions, that would make use of and build on urban nature, to the increasing societal challenges spread with the introduction of the term Ecosystem Services, first in 1997 (Costanza et al., 1997) and then with its international recognition through the Millennium Ecosystem Assessment in 2005 (MEA, 2005). The Ecosystem Services framework firstly provided the methods and proposed indicators to quantify the benefits that ecosystems provide humans with and opened a huge debate on how to better plan, design, manage, evaluate, and assess ecosystems around the world.

As for urban areas the importance of urban ecosystem services raised later in time (Haase et al., 2014), but it is now increasingly gaining attention in science, policy and practice concerning urban sustainability and resilience. Different terminologies and concepts have been used in the last decades to define instruments, tools and solutions that refer to the use of ecosystems and nature to tackle a broad range of challenges and to improve humans' wellbeing and health. Whether some of these concepts have been uptake and spread by international organizations and research centres, it is however worth to highlight that the North-South divide is evident in terms of scientific publication productivity and funding for this type of research (Escobedo et al., 2019). Indeed, most of these terms were developed and applied first in high-income societies and are driven by an approach that emphasizes engineering and economic-based quantification of ecosystem processes and values (Anguelovski & Martínez Alier, 2014). Just recently they are applied in the Global South amidst its realities of pollution, inequities in resource access and other environmental injustices. Table 4-1 summarizes, in a non-exhaustive way, the main definitions and related characteristics in terms of scale, project phases and functions of the most common terms regarding nature in cities, while as from the next paragraph this work will focus on Ecosystem Services (ES), Green and Blue Infrastructure (GBI) and Nature-Based Solutions (NBS) as the most relevant concepts for urban planning.

Table 4-1 Non-exhaustive overview of concept related with nature in the city (Author elaboration based on Ahern, 1995 and Nesshover et. Al, 2017

Term/Concept	Definition	Scale (Building, Urban, Regional, National, European)	Project phase (Planning, Implementation, Monitoring, Evaluation, Assessment)	Declared Function (Ecological, Social, Mobility, Economic, Health-related)
Greenbelts	The notion of landscape as a separator of city and hinterland refers to the middle-age constellation of a contradiction between city and countryside (Mumford, 1961)	Urban	Planning Implementation	Social
Greenways	Transport routes dedicated to light non-motorised traffic (T. Turner, 2006); Communication route which has been developed for recreational purposes and/or for undertaking necessary daily trips, 'former transport routes in a specific location, partly or completely decommissioned, and which once properly restored, are made available to users of non-motorised transport such as pedestrians, cyclists, people with limited mobility, roller skaters, cross-country skiers, horse riders, etc. (European Greenways Association, 2000). More recent Urban greenways which are often designed with multi-use trails that provide opportunities for physical activity, recreation and transportation are defined as places for nature in the city where people can fulfil recreational needs and achieve solitude and retreat without leaving the public realm (Akpinar, 2016).	Urban Regional	Planning Implementation	Mobility and transport, Social
Ecological and Wildlife corridors	They are a mean to face habitat fragmentation providing green and safe spaces linking habitat patches. Corridors can mitigate some of the negative effects of development on wildlife, especially where they facilitate the movement of large predators (Soulé, 1991)	Urban. regional	Planning, implementation	Ecological – in terms of habitat fragmentation and biodiversity loss
Ecosystem based adaptation	The adaptation policies and measures that take into account the role of ecosystem services in reducing the vulnerability of society to climate change, in a multi-sectoral and multi-scale approach. EBA involves national and regional governments, local communities, private companies and NGOs in addressing the different pressures on ecosystem services, including land use change and climate change, and managing ecosystems to increase the resilience of people and economic sectors to climate change (Vignola, Locatelli, Martinez, & Imbach, 2009).	Urban, regional, national	Planning	Ecological – in terms of climate adaptation
Natural Water Retention Measures	Natural water retention measures are measures that aim to safeguard and enhance the water storage potential of landscape, soil, and aquifers, by restoring ecosystems, natural features and characteristics of water courses and using natural processes. They support Green Infrastructure by contributing to integrated goals dealing with nature and biodiversity conservation and restoration, landscaping, etc. They are adaptation measures that use nature	Buildings, urban, regional	Implementation	Ecological – in terms of ecosystem conservation and restoration, biodiversity and risk management

	to regulate the flow and transport of water so as to smooth peaks and moderate extreme events (floods, droughts, desertification, salination). They are a better environmental option for flood risk management (European Commission, 2012)			
Natural Capital	Natural capital is the stock of living and non-living parts of the natural system that directly and indirectly yield benefits to humans (Nesshöver et al., 2017) Other definition also includes geological and biophysical components (e.g. Natural Capital Coalition, 2016) or may explicitly encompass interactions and processes that form natural systems (Natural Capital Initiative, 2016).	Urban, regional, National, European	Monitoring, evaluation and assessment	N/A
Urban Forest	Urban Forest is the network comprising all woodlands, groups of trees and individual trees located in urban and peri-urban areas (e.g. street trees, remnant, and planted forests, public and private individual trees (Escobedo et al., 2019).	Urban	Planning, implementation	Ecological
Green and Blue Infrastructure	A strategically planned and managed, spatially interconnected network of multi-functional natural, semi-natural and man-made green and blue features including agricultural land, green corridors, urban parks, forest reserves, wetlands, rivers, coastal and other aquatic ecosystems (European Commission, 2013)	Buildings, urban, regional, national	Planning, implementation	Ecological, Social, Mobility, Economic, Health-related
Ecosystem Services	Ecosystem Services are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems (Costanza et al., 1997). An approach to understand how natural systems can benefit humans, by linkages between ecosystem structures and process functioning and consequent outcomes which lead directly or indirectly to valued human welfare benefits (gains or losses) (Turner and Daily 2008).	Urban, Regional, National, European	Planning, monitoring, evaluation and assessment	Ecological, Social, Economic, Health-related
Nature Based Solutions	NBSs are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions (European Commission, 2015)	Urban, Regional	Planning, implementation	Ecological, Social, Economic, Health-related

4.2 ECOSYSTEM SERVICES, GREEN AND BLUE INFRASTRACTURE AND NATURE-BASED SOLUTIONS

In the scope of this work, we mainly refer to Ecosystem Services (ES), Green and Blue Infrastructures (GBI) and (Nature-Based Solutions) NBSs to develop on nature into the cities, as these definitions are becoming increasingly influential into sustainable and resilient policies, planning, practices and approaches.

While the term Ecosystem Services (ES) appears in 1997, Green and Blue Infrastructure (GBIs) usage raised around 2007, mostly in North American and European countries. The definition of Nature-Based Solutions (NBSs) was introduced in 2012 by IUCN, followed by a re-definition from the European Commission in 2015 that strongly contributed to its widespread adoption in EU countries.

4.2.1 ECOSYSTEM SERVICES

The emerging research field of urban ecology tries to overcome the classical divide between nature and city by merging ecosystem science with insights from urban planning leading to the understanding of cities as coupled social-ecological systems (Childers et al., 2015; Dearing et al., 2014; McPhearson et al., 2016a; Niemelä & McDonnell, 2013). Urban areas and natural areas are thereby understood on the one side as integrated parts of the earth's larger ecosystems and on the other side as integral part of the urban realm (Niemelä, 1999). Departing from this understanding, the boundaries between cities and adjacent ecosystems become diffused, as do the flow of their services and the limits between urban areas and green spaces nested within them.

The conceptualization of the idea that ecosystems provide humans with a set of specific benefits and services have reached a worldwide recognition with the Millennium Ecosystem Assessment, 2005. The definition that came out from that momentum summarizes the 'anthropocentric' conception of the term, stating that Ecosystem Services (ES) '*are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing: that is, the benefits that people derive from functioning ecosystems*' (Millenium Ecosystem Assessent, 2005). From that moment research and practices on the potential implementation of such extensive framework have grown significantly. The Millennium Ecosystem Assessment, the Economics of Ecosystems and Biodiversity global initiative (TEEB, 2010) and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) have brought the concept into broader research, planning and policy arenas. Subsequently, the integration of such framework into the urban sustainability discourse also raised, underlying the crucial role of urban ecosystems and related benefits into cities' path towards sustainability and resilience (Brunner and Grêt-Regamey 2016; Gómez-Baggethun and Barton 2013; McPhearson, et al., 2013).

Generally, ES are classified into four main categories: provisioning, regulating, cultural and supporting or habitat services (MEA, 2005; TEEB, 2010). Provisioning ES include all the processes and the ecological structures that underpin the creation of materials and elements crucial for human life, such as food, fresh water or medicinal resources. Also provisioning services include mineral and non-mineral substances or ecosystem properties used for nutrition, materials or energy. All renewable resources energy can be considered as provisioning ecosystem services. Regulating ES refer to the capacity of ecosystems to regulate or moderate the environment and its processes, including climate regulation, moderation of extreme events, erosion prevention or biological control. Regulating ES are thus core in climate mitigation and adaptation strategies. Cultural Ecosystem Services (CES) are the non-material, intangible outputs of ecosystems that affect physical and mental states of people, for example through spiritual experience, physical and cultural recreation, aesthetic appreciation, environmental education or sense of place. Finally, supporting or habitat ES are defined as the ecological processes and functions that are necessary to produce the previous ecosystem services, including habitat for species and maintenance of genetic diversity. As introduced by the Millennium Ecosystem Assessment (MEA), the Ecosystem Services framework aimed at defining and quantifying those interactions and relations as benefits or trade-off that people obtain from ecosystems. The MEA and subsequent ecosystem services literature (Costanza 2008; Fisher et al., 2009; Kandziora et al. 2013; Wallace 2007) have developed different conceptual and empirical frameworks leading to various interpretation and application of ecosystem services and related terminology and definitions (La Notte et al., 2017). Among the different definition, the Common International Classification for Ecosystem Services (CICES), proposed by the European Environment Agency, has become an important frame of reference for ecosystem services research (Maes et al., 2013). Similar to the TEEB classification, CICES does not include the MEA (2005) 'supporting services', but merges the TEEB (2010) 'habitat services' with regulating services, in a category called 'regulating and maintenance services'. While the concept of Ecosystem Services widely raised among ecological, biodiversity and natural sciences related studies (see MEA, 2005), attention paid to urban areas was initially modest. The concept of cities as complex socio-ecological systems (Frank, 2017; Mascarenhas et al., 2015) frames the idea of urban areas as hot-spots of human and nature networks, interactions and relations.

Since the pivotal paper by Bolund and Hunhammar, 1999, a growing body of literature has advanced our understanding of urban ES (Gómez-Baggethun & Barton, 2013; Haase et al., 2014; Larondelle, Haase, & Kabisch, 2014b; McPhearson et al., 2016b). Concerning supporting and regulating ES, this dissertation largely follows the nomenclature used in this classification of urban ES (see also ómez-Baggethun and Barton 2013). Provision ES are included in the following list, as they are considered crucial for sustainable future of urban realm, mostly in relation with sustainable local food production, even though this won't be object of this study. Cultural ES categories and definitions have been adapted from Gómez-Baggethun et al. 2013, CICES v5.1, and Kandziora et al. 2013.

- Regulating services:

1. Air purification - GBI in urban systems improve air quality by removing pollutants from the atmosphere, including ozone ($O3$), sulphur dioxide ($SO2$), nitrogen dioxide ($NO2$), carbon monoxide (CO) and particulate matter less than 10 μm (PM10) (Baró et al., 2014).
2. Global climate regulation or carbon storage: referred as Filtration/ sequestration /storage /accumulation by micro-organisms, algae, plants, and animals in the CICES V5.1. It refers to the capacity of GBI of storing, filtering or accumulating emissions of greenhouse gases in cities include carbon dioxide ($CO2$), methane ($CH4$), nitrous oxide ($NO2$), chlorofluorocarbons (CFCs), and tropospheric ozone ($O3$).
3. Micro-climate regulation or Urban temperature regulation – GBI in cities regulates local temperatures and buffers the effects of urban heat islands (Gómez-Baggethun et al., 2013). Regulation of temperature and humidity, including ventilation and transpiration (CICES 5.1)
4. Noise reduction and attenuation: GBI can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound waves (Gómez-Baggethun et al., 2013).
5. Water flow and Run-off control and mitigation: referred as Hydrological cycle and water flow regulation (Including flood control, and coastal protection) in CICES 5.1. Urban GBI reduce surface runoff following precipitation events by intercepting water through the leaves and stems. This process contributes to mitigate climate change increasing events such as urban flooding, flash floods.
6. Waste and water treatment: GBI filter out and decompose organic wastes from urban effluents by storing and recycling waste through dilution, assimilation and chemical re-composition (Gómez-Baggethun et al., 2013).

7. Pollination: Allotment gardens i.e. a plot of land made available for individual, non-commercial gardening), private gardens that favour pollinators, seed dispersal and pest management (Gómez-Baggethun et al., 2013 and CICES 5.1).

- Cultural services:

1. Physical recreation: Physical and experiential interactions with natural environment (CICES V5.1), and outdoor activities relating to the local environment as form of sports or active mobility (adapted from Kandziora et al. 2013) – cycling, hyking, trailing, swimming, etc.
2. Experiential and Cultural recreation: Physical and experiential interactions with natural environment that don't include active physical activities or sport. Outdoor activities or tourism relating to the local environment including leisure. In this dissertation this includes also the aesthetic benefits as intangible value that is measured by "man's search for pleasure, pleasantness, discovery that takes place in his free time and outside the space in which he lives" (Vasiljevic & Gavrilovic, 2019).
3. Cognitive development and educational value: Intellectual and representative interactions with natural environment (CICES 5.1). Environmental education based on ecosystems and landscape features - i.e outdoor schools, urban forests and allotment gardens are often used for environmental education purposes (adapted from Kandziora et al. 2013) facilitating cognitive coupling to seasons and ecological dynamics in technological and urbanized landscapes (Gómez-Baggethun et al., 2013).
4. Social relations and cohesion: Attachment to green spaces in cities can also give rise to other important societal benefits, such as social cohesion, promotion of shared interests, and neighbourhood participation. Elements of living systems used for entertainment by a group of people (adapted from CICES 5.1). A benign social group, including access to mates and being loved (Wallace, 2007).

- Supporting services:

1. Habitat for species (refugia) Urban systems can play a significant role as refuge for many species of birds, amphibians, bees, and butterflies (Gómez-Baggethun et al., 2013).

- Provisioning services:

1. Food production: allotment gardens, community gardens and innovative urban farming and agricultural techniques can support sustainable food production (Breuste & Artmann, 2015).

2. Fresh water (water supply): the provision of drinking water, irrigation water, hydropower (Gómez-Baggethun et al., 2013)

Although most of the attention is focused on evaluating and assessing ecosystem services, it is important to also mention the possible trade off generate by ecosystem to human being, called ecosystem disservices. Indeed, allergenic pollen, spread of diseases, are issues of raising concerns in urban planning and GBI design. These disservices will not be part of this dissertation.

The processes and the causal relation that contribute to generate ES have been deeply studied after the MEA was published. CICES and most ecosystem services literature that we now refer to, are based on and influenced by the cascade framework proposed by Haines-Young & Potschin (Haines-Young & Potschin, 2016; Potschin & Haines-Young, 2011). The ES cascade framework links natural systems to elements of human well-being, following a pattern similar to a production chain: from ecological structures and processes generated by ecosystems, to the services and benefits eventually derived by humans.

The ES-cascade model developed by Haines-Young & Potschin consists of five main elements: i. *Ecosystem structure*, ii. *processes (or functions)*, iii. *ecosystem services*, iv. *benefits and v. values* (Fig. 4-4).

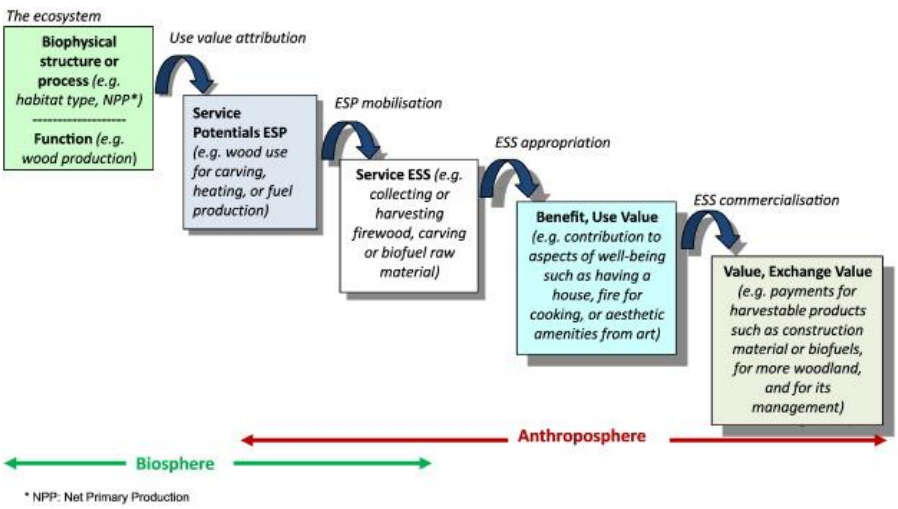


Figure 4-4 Ecosystem structures, values, processes and functions (Spangenberg et al., 2014)

Ecosystem structure comprises all abiotic and biotic elements of an ecosystem (including those created by humans) and, within urban areas, represent the natural capital embedded into exiting green and blue infrastructures. Ecosystem processes or functions define the potential or capacity of an ecosystem to provide ES. Ecosystem services themselves are then described as the flow of benefits from the ecosystem to humans, whereas benefits and values describe the human perception and appreciation of ES (de Groot et al. 2010, TEEB, 2010). The flow of ES is thus supported by the interfaces between the non-living environment, living organisms such as plants and animals, as well as human *perceptions* and values which stipulate management practices (Langemeyer & Connolly, 2020; Van Oudenhoven, Petz, Alkemade, Hein, & De Groot, 2012). In this way, ES conceptually links the ecological structures and processes of urban green and blue infrastructure to human *demands*, appreciations and wellbeing.

The framework developed by Gómez-Baggethun et al. 2014 within the OpenNESS project (Fig.4-5) well embedded the ES cascade model within the ideas of cities as complex adaptive socio-ecological system, defining the supply side as the biophysical structures and its related functions, and linking it to the demand side, made by the social systems, through the Ecosystem Services flow. The value domain then includes both the socio-cultural component and the economic /monetary domain of the value generated by the benefits.

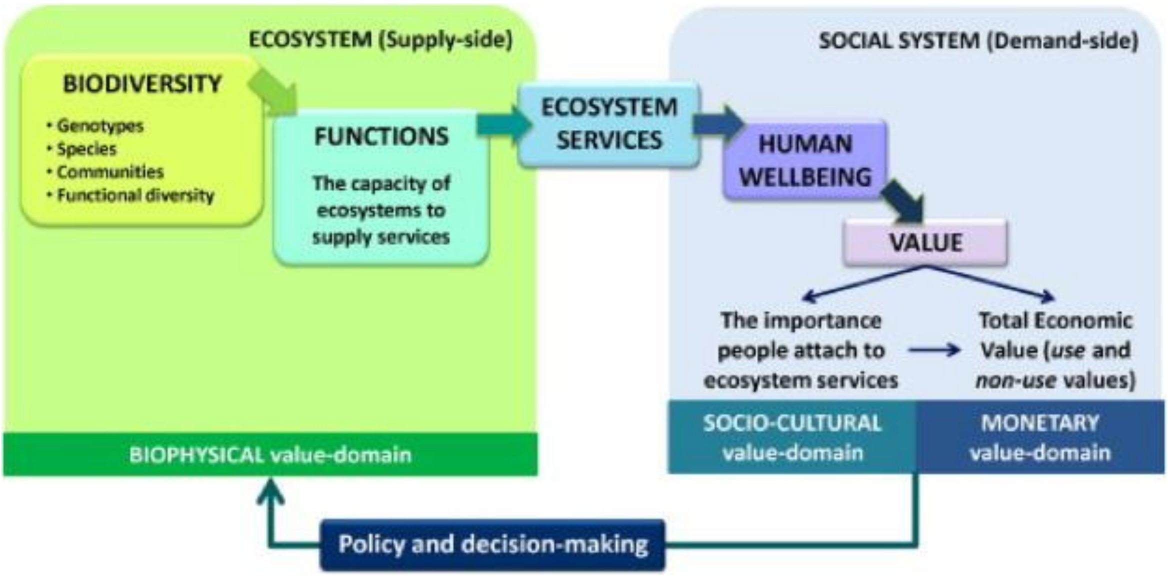


Figure 4-5 EU FP7 OpenNESS Project Deliverable 4.1., Gómez-Baggethun, E., B. et al, 2014

This framework (Fig. 4-5) introduced policy making as a crucial component deriving from the social system (*demand*) but able to influence the ecological system (*supply*). Studies on ES for supporting policy making should then build on a wide understanding of ES supply, capacity, flow and demand (Crossman et al., 2013; Schröter et al., 2014; Villamagna, Angermeier, & Bennett, 2013). Within urban areas, while ES supply within the city is made by its biodiversity (Gómez-Baggethun et al. 2014) and ecosystem structure (Potschin and Haines-Young 2011), ES capacity can be defined as '*the ecosystem's potential to deliver ES based on its structures, processes and functions under the current management* *of the ecosystem*', ES flow as "*the ES actually received, used or experienced by people*", and ES demand as "*the amount of a service required or desired by society*" (Villamagna et al., 2013). The methodological approach of this dissertation will follow an adapted frame of the ES cascade model. Understanding the capacity, real flow of benefits and the actual demand from citizens would support policy and decision makers to better plan and design multifunctional GBI and NBS according to population needs and would largely support cities transition towards sustainability and resilience.

4.2.2 GREEN AND BLUE INFRASTRUCTURES (GBI)

Green and blue infrastructures (GBI) have been identified in the last decades as one of the most interesting and promising strategy for achieving sustainability. One of the first definition of GBI has been given by the Conservation Fund (2004) delineating them as '*the interconnected network of natural and semi-natural areas, features and green spaces that support native species, maintain natural ecological processes in rural and urban areas, and contribute to the health and quality of life for human beings*' (The Conservation Fund, 2004).

With the same vision and objectives in mind, the EU Commission proposed in 2013 the strategy on Green infrastructure to enhance Europe natural capital. Within this strategy, GBI are defined as *'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services such as water purification, air quality, space for recreation and climate mitigation and adaptation. This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, creates job opportunities and enhances biodiversity. The Natura 2000 network constitutes the backbone of the EU green infrastructure'* (European Commission, 2013)

Compared with the previous ones, this definition strongly connects GBI with the ecosystem services they can provide, and it includes at the same level green and blue spaces; moreover, by mentioning Natura 2000 network as the main backbone of EU green infrastructure, the urban dimension of GI appears to be less evident than in the Conservation Fund definition, that was focusing on citizens' health and quality of life as the main impacts to be considered. Nevertheless, as also mentioned by Wang and Banzhaf 2018, the scale, the range, the extent and the implementation of such solutions can strongly vary from case to case as well as the benefits and the impacts they can produce on human wellbeing and health and on the environment. In line with the ES cascade-model proposed by Potschin & Haines-Young, 2011, a conceptual framework for assessing multifunctionality in GBi planning has been proposed by Hansen et Pauleit, 2014 that focused on GBI multifunctionality within complex socio-ecological system. Also this framework proposed to look at the ecological system, as the supply side of relevant ES, and at the social system, considered as the demand side. Both perspectives in the framework are considered to determine priorities for strategies and actions. While few cases in Europe adopted dedicated green infrastructures strategy and plans, i.e most of British cities and Barcelona developed entirely dedicated strategies, several cities and regions are still working at the concept integrating it in different planning, environmental or mobility related policies (Davies et al., 2015).

On the other side, effort in research (e.g. Bartesaghi Koc, Osmond, and Peters 2017; Mazza et al. 2011; Pauleit et al. 2019) focused on defining the intrinsic green and blue infrastructure elements, and their features in urban areas. According to Mazza 2011, the main green infrastructure elements are: Green Urban and Peri-Urban Features Parks, gardens, small woodlands, grass verges, green walls and roofs, Sustainable Urban Drainage Systems (SUDS), school fields, cemeteries, allotments, street trees, ponds (Mazza et al., 2011). This definition does not include the blue spaces, such as lake and pond, river, canal, estuary, delta and costal ecosystems often part of city boundaries (Pauleit et al., 2019). The GREENSURGE project (FP7 GA: 603567) defined GBIs not just in terms of green and blue features and elements that composed them, but also according to the type, dividing them in eight groups of urban green (Fig. 4-6).

Figure 4-6 Green and Blue Infrastructure elements and features per type of urban green (Pauleit et al. 2019)

Such groups considered both natural elements and mixed natural and man-made elements. In the list below they will be presented from the more hybrid to the most natural features:

- Building Greens
- Private commercial, industrial, and institutional green spaces – green spaces connected with the grey infrastructure
- Riverbank green
- Parks and recreation
- Allotment and community gardens
- Agricultural land
- Natural, semi-natural and feral areas

4.2.3 NATURE BASED SOLUTIONS (NBS)

One of the first specific reference to the term Nature-Based Solutions can be found in the late 2000s in a report of the World Bank focusing on solutions to mitigate and adapt to climate change (MacKinnon et al., 2008). In this report, attention is mostly focus on nature, while biodiversity preservation and urban environment are hardly mentioned, and the proposed concept does not differentiate much from the previous definitions of GBI. In 2015, the EU Commission set up an expert group on Nature-Based Solutions and re-naturing cities (European Commission, 2015), which set the way towards a dedicated funding stream within the Horizon 2020 funding programme. Building on this report, the EU Commission in 2016 adopted the following definition: '*NBSs are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions*'. Within this definition, the role of NBSs as solutions to pre-identified societal challenges within cities assumes a strong relevance, while at the same time, the focus on mimicking, which was clearly mentioned in the expert group report, appear to lose relevance.

The IUCN definition, 2016, built on the idea of Nature-Based Solutions as one of the possible strategies to tackle societal challenges defining them as '*actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*' (Cohen-Shacham et al., 2016).

The introduction of the NBS concept into science, policy and practices, due to the broad framing of its definitions, can appear vague, and the links to pre-existing concepts may be unclear and the conceptual flexibility associated with a vague term can negatively affect the management of natural resources (Nesshöver et al., 2017). It is then quite important to clarify the usage of the different terminology and how NBS concept builds on and supports other closely related concepts, such as ES and GBI.

As reported by the experts' group of the European Commission, all these terms recognise and acknowledge the role of nature into urban environments and require a systemic approach to socio-ecological and economic drivers of change, based on an understanding of the structure and functioning of ecosystems, including human actions and their consequences.

With respect to GBI, ES, NC or other concepts presented in Table 4-1, NBS include some slightly different pre-conditions: (i) the idea that societal challenges raised from the impacts human had on the same ecological system they live; (ii) sustainable alternatives, mitigation activities or entirely new sustainable processes to meet societal challenges can be found by looking at nature for design and process knowledge. Then, conceptually, they *involve the innovative application of knowledge about nature, inspired and supported by nature, and they maintain and enhance natural capital. They are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives* (European Commission, 2016). With respect to previous definitions, the main novelty lies within NBS multifunctionality and challenge- oriented by definition and the use of nature as socio-economic, and not just ecological, problem-solver. This conceptual framework that embeds a trans-sectorial, trans and multi-disciplinary approach and that looks at cities as complex socio-ecological systems, with inherent and external drivers of change (climate, environmental social and economic drivers) can largely support a shift towards more sustainable and resilient planning.

Nevertheless, it would be also crucial to agree that, at an operational scale, the NBS concept can sometimes be synonymous of GBI, though differences between "infrastructure" vs. "solution, and that ES could usefully inform NBS, providing a common currency for assessing and evaluating the consequences of differing solutions (Nesshöver et al., 2017; Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017a).

Mostly in Europe, also due to the dedicated NBS funding stream of the Horizon 2020 programme (see Chapter 3), NBS categorization and typology is also of great interest for researchers and practitioners. Building on Almenar et al. 2021; Eggermont et al. 2015 proposed a new NBS typology, dividing NBS into 3 main types:

- NBS Type 1 are considered solutions that permit not only a better use, but also a better management (i.e. non-physical modifications) of existing natural or naturalistic ecosystems.
- NBS Type 2 include solutions and procedures to restore ecosystems. These are further differentiated into reclamation and restoration categories.
- NBS Type 3 are solutions that involve creating novel ecosystems. These also include solutions that involve the extensive (i.e. a large percentage of area) and intensive (i.e. high degree) modifications of existing ecosystems. This would be the case of converting a highly artificialized urban green area into a highly naturalised one.

While NBS Type 1 and Type 2 include most of the previously called ecosystem-based adaptation (Geneletti & Zardo, 2016), only urban case studies referring to (semi)natural ecosystems and NBS Type 3 are found. The most frequently studied NBS Type 3 per type of media are green roofs, green walls, woodland-like structures, urban grasslands and meadows, urban scrubland and heathland, horticultural gardens, vegetated filter strips, swales, constructed wetlands, natural(ised) wetlands, natural(ised) ponds and bioretention basins. NBS type 3 could then also be associated with the definition of GBI provided in Fig.5.4. Almenar et al. 2021 illustrated a clear prevalence of Type 3 in urban ES studies, associating it to a *strong need to bring back natural structures into cities* and possibly because of the perception that *the creation of new ecosystems would be more effective solutions for addressing Urban Challenges (UC)*. At the same time, probably *urban environmental management and urban ecological restoration might not usually be framed in the research area of ES and* for the assessment of the individual contribution of NBS Type 1 to ES supply it might be necessary to compare changes in the supply of ES by the same physical structure before and after an NBS Type 1 or 2 was applied so that timing would still be too short respect with the introduction of the NBS terminology.

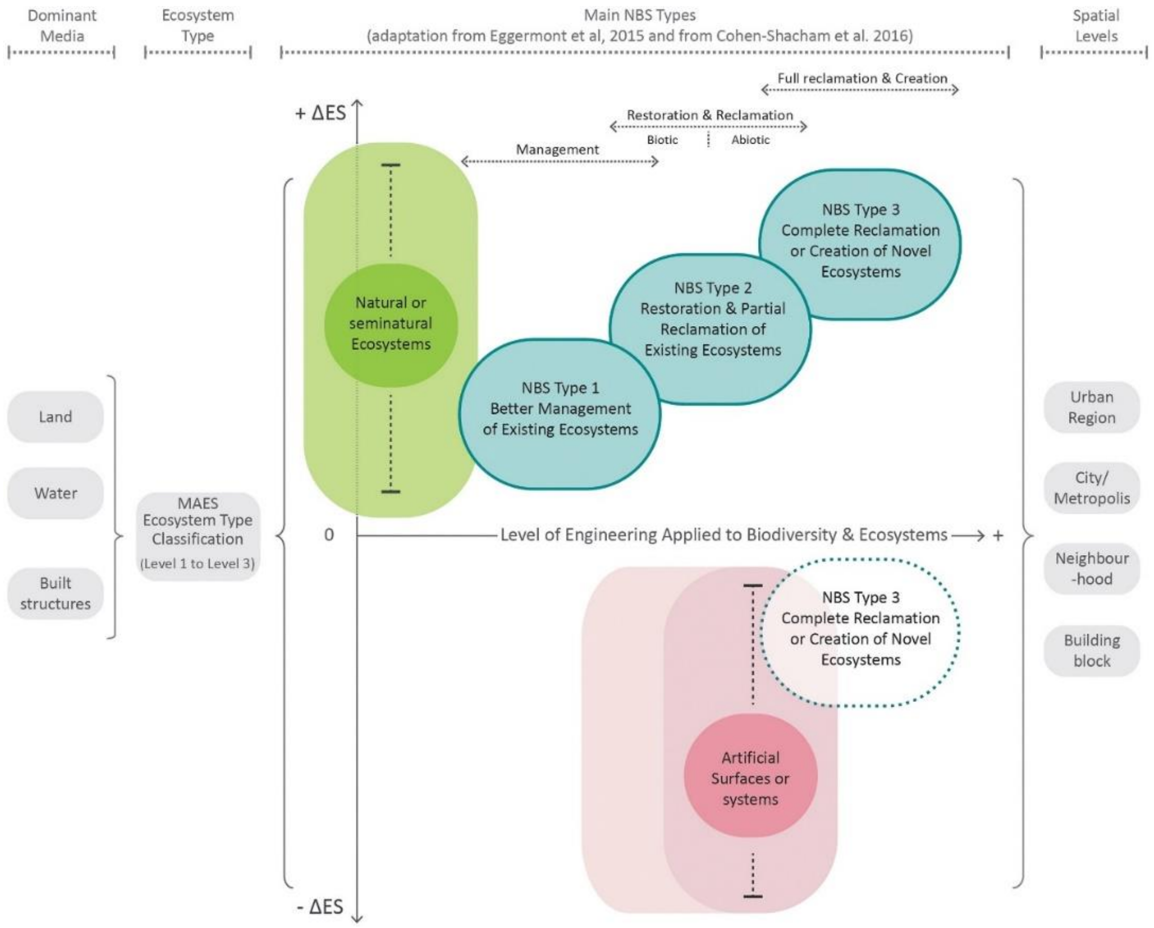


Figure 4-7 NBS types according to Almenar et al. 2021

Also, within the same study, Almenar et al. 2021, through a two-step systematic and non-systematic review, defined a relation between ES and related NBS type 3. Type 3 NBS have been further divided into built structures (green roofs and green walls) land media (urban forest, horticultural gardens and orchards) and water media (naturalized wetlands and ponds, bioretention basin and vegetate filter strips). While Fig. 4-7 already offer useful information to planners, industry, and local authorities on the type of benefits provided by the different NBS, it should be added that innovation in NBS is an intrinsic part. Thus, new form of NBS have not been studies yet and could become even more relevant in the provision of specific ES.

4.2.4 GREEN AND BLUE INFRASTRUCTURES, ECOSYSTEM SERVICES AND NATURE-BASED SOLUTIONS: RELATIONS

Building on the concepts presented in the previous paragraphs in this context and although ES, GBI, and NBS share similar roots, we argue that NBS, GBI and ES can all be considered conceptual and operational approaches within urban planning, but that they assume different roles during urban transition processes.

Within this work, as presented in Fig 4-8, the ES framework is considered as a methodological framework to assess nature's benefits and to inform policy and decision makers (i.e integration into EIA and SEA of local project and plan, knowledge building during the pre-planning phase) on such benefits' distribution, flows, mismatches and shortage, if any. ES supply and capacity assessment offer core information over ecosystems' condition and health, degraded ecosystems, and are useful information to plan their design, management, and resilience over the time. On the other side, ES

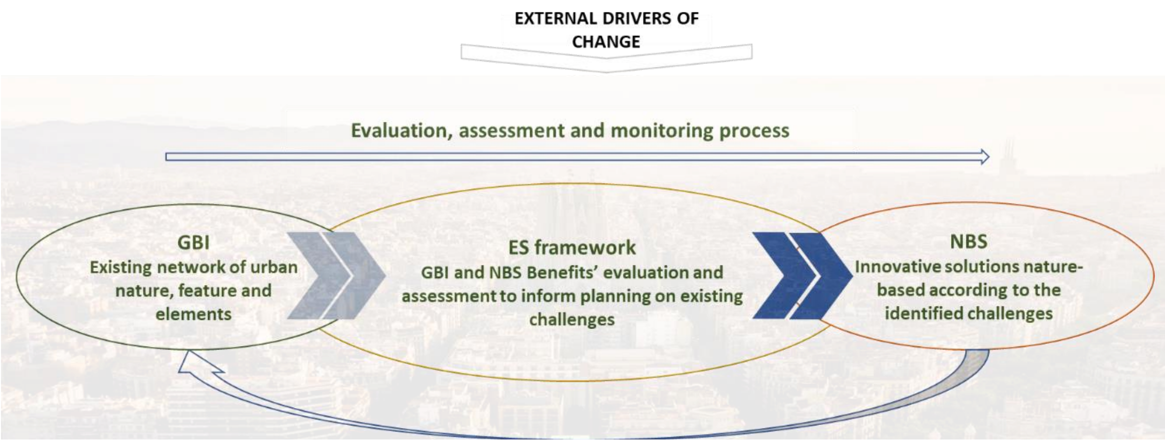


Figure 4-8 GBI, ES and NBS concepts in relation with the planning process. (Author elaboration)

flows and demand evaluation provides useful information on citizens' behaviour and preferences understanding their perceptions, needs and vulnerabilities.

Also, according to already mentioned studies and literature (Almenar et al., 2021; Nesshöver et al., 2017; Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017b) the term GBIs will be used to define the overall network of existing urban green areas, elements, and features, referring to the definition provided in Fig.1, coinciding with the ES supply definition. On the other side, while many authors considered NBS as an umbrella concepts under which all the other related terms can be related with, we will refer to NBSs in the context of new of urban green areas, elements, and features that would include innovative planning, governance, financial and participatory framework and that should be planned and designed as:

- Multifunctional solutions to challenges identified based on socio-ecological evaluation of ES capacity, flows and demand according to the analysis of the existing urban GBIs
- Multifunctional solutions to trans-sectorial challenges identified by sectors other than environment and planning (i.e health, housing, mobility).

Multifunctionalities in reference to pre-identified challenges, co-development and innovation with regards to institutional, financial and governance issues and the process to see nature as a solution to existing issues, are the main innovation brought by the NBS concepts. Studies and practices will be needed to clarify and properly make use of the different terms, so that metaphors don't create confusion, but actually work synergistically together (Escobedo, Giannico, Jim, Sanesi, & Lafortezza, 2019).

4.3 ECOSYSTEM SERVICES FOR SUSTAINABILITY AND RESILIENCE

4.3.1 URBAN SUSTAINABILITY AND RESILIENCE

Sustainability encompasses, by definition, three interrelated spheres: economic, social and environmental that should not compete but rather collaborate towards a sustainable future. Nevertheless, when sustainability is coupled with the term development, the risk is that the overall focus switch to economic development rather than overall sustainability (Verma & Raghubanshi, 2018) and the social and the environmental sphere are left apart, draining earth's regenerative and carrying capacity and exacerbating injustice and inequalities in the social sphere. The underlying idea is that economic growth must be sought to increase human quality of life and overall wellbeing tend to be left apart. The environmental and the social spheres of sustainability are then often misplaced among sustainable development priorities. De-growth theories affirmed that quality of life can be sustainable without steady economic growth , if a deep and rational use and redistribution of resources would be applied, both within cities and ecosystems and, more globally, among countries (Kallis et al., 2018). When applied to cities, sustainability can be seen as an approach to rationally use resource and manage waste production in a way that stays below *the carrying capacity of their supporting ecosystems, while ensuring a capacity for sustaining life, social practices and quality of life, deemed acceptable by current and future members of a social system such as a city* (Romero-Lankao et al., 2016b).

Guaranteeing a just and equal distribution of benefits among citizens in the future would largely contribute to the three spheres of urban sustainability. The concept of environmental and climate justice (Ikeme, 2003; Romero-Lankao et al., 2016b) discuss the established rights to use natural resources, to benefit from ecosystem services, but at the same time to deteriorate ecosystems and emit pollutants. At the same time, the environmental and climate justice discourse reflects on who is more affected by the unsustainable use of resources and its consequences (land-use change, climate change) and who should be responsible of ameliorating those impacts, and reducing environmental risks. As previously mentioned in Chapter 2, the environmental and climate justice principles are applied, at least theoretically, to current international agreement on climate change and sustainable global development, recognizing the Global North as the main responsible of the current situation, thus responsible for most of GHG emission reductions and development projects in the Global South. Coherently, we could apply such an approach to the city realm (Rutt & Gulsrud, 2016; Wolch, Byrne, & Newell, 2014) trying to answer the following questions: who in the city has the right to use resources and benefit from ecosystem services? Who is the responsible and has the right to ameliorate impacts and to ensure a just and equal distribution of such rights? Answering to these questions would contribute to support cities towards an inclusive sustainability.

Lately, the concept of urban sustainability is often twinned with the idea of urban resilience and the two terms are used almost interchangeably in some cases, leading to some confusion and misleading interpretation.

While urban sustainability, as well as ecosystem services, is considered a normative concept representing a (positive) vision for the future of the society (Romero-Lankao et al., 2016b; Schröter et al., 2014), urban resilience is generally vaguely defined, which makes it difficult to be used as an analytical framework (Meerow, Newell, & Stults, 2016; My M Sellberg, Wilkinson, & Peterson, 2018) (Meerow et al. 2016; Sellberg et al. 2018).

Holling (1973) defined *resilience as an ecosystem's ability to maintain basic functional characteristics in the face of disturbance*. Characterizing ecosystems as having multiple stable states and in a constant state of flux, Holling (1996) later distinguished between static "engineering" resilience, referring to a system's ability to bounce back to its previous state, and *dynamic "ecological" resilience, which focuses on maintaining key functions when perturbed*. Socio-Ecological Systems (SES) studies added another layer to previous definition considering nature-society as an intertwined, coevolving system (Meerow et al., 2016). In the SES literature, resilience is identified as a product of (1) the amount of perturbation a system can endure without losing its key functions or changing states, (2) the system's ability to self-organize, and (3) the system's capacity for adaptation and learning (Folke et al., 2002). This conceptualization of resilience intrinsically brings the idea of continuous change, disturbances, and uncertainty in the management of socio-ecological complex systems (Biggs et al., 2012; Biggs, Schlüter, & Schoon, 2015).

Urban realms are Socio-Ecological Complex system by definition, thus, the integration of resilience into urban policies and discourses raised fast and incrementally in the last decade making resilience at the top priority of city's future design and planning. Urban resilience would be crucial to achieve long-lasting sustainability in a world of transformation (Folke et al., 2002; Meerow et al., 2016).

After reviewing several concepts and resilience theory, Meerow, Newell, and Stults 2016 defined urban resilience as '*the ability of an urban system—and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales—to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity*'.

Resilience has often been interpreted as being per se positive, which could be misleading. In this regard, (Elmqvist et al. 2019) introduced a more precise understanding of urban resilience in the face of sustainable transformations of urban areas.

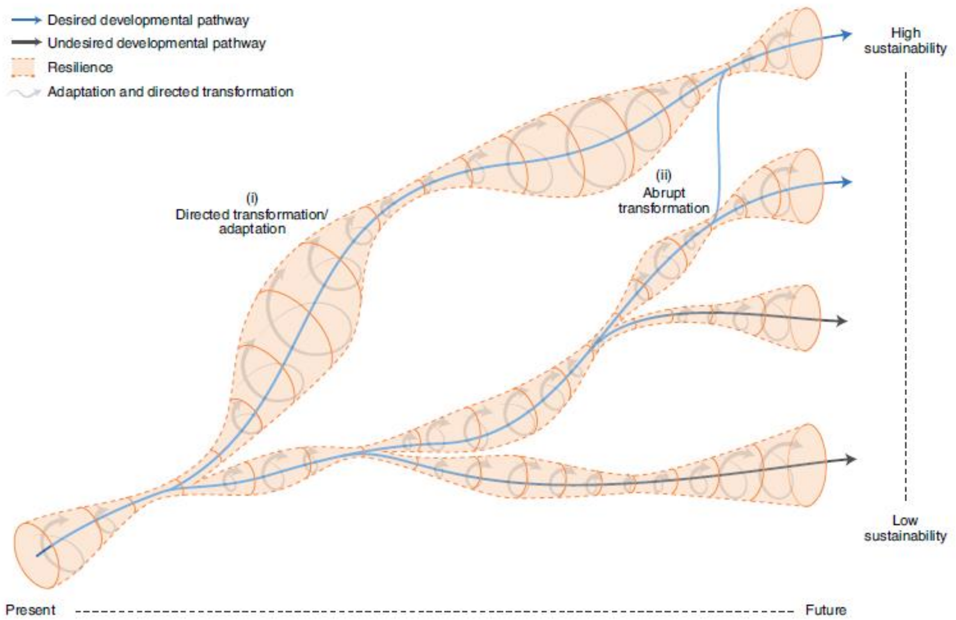


Figure 4-9 Urban sustainability, resilience and abrupt transformation (Elmqvist et al, 2019)

They describe resilience as a neutral, non-normative concept and an intrinsic property of a system, as the '*capacity of an urban system to absorb disturbances, reorganize and maintain essentially the same functions over time and continue to develop along a particular trajectory*' (Elmqvist et al. 2019).

This interpretation suggests that if the pathway a city is following is not sustainable, then resilience forms a barrier to the desired transformations and *should rather be reduced in order to move the cities' trajectory towards a more sustainable pathway* (see Fig. 4-9). A resilient and accessible flow of ES is a critical aspect of a more sustainable trajectory as it would help secure human wellbeing in face of challenges related to climate change and social transformation. Tailored policies should rather remove unwanted resilience to the flow of ES benefits in order to transition towards easier access and more equitable distribution of benefits. The need for building urban resilience has increasingly gained attention in the last decade both in science and in practice, as resilience theory helps to understand complex socio-ecological systems and their sustainable planning and management, not least with respect to climate change (Elmqvist et al. 2019). Yet, resilience research and practice are too often narrowly focussed on single external drivers of change, for example climate change, and tend to overlook the combination, interaction, and feedbacks between different external drivers of change and inherent systems' dynamics.

4.3.2 URBAN SUSTAINABILITY THROUGH ECOSYSTEM SERVICES, GBI AND NBS

Urban sustainability and resilience address several common topics like biodiversity, energy, material balance, air pollution, heat island, noise pollution, etc. Sustainable and resilient urban strategies, policies and intervention, have the potential to buffer local and global impacts and enhance quality of life of the inhabitants, driving local and global sustainability actions and impacts (Almenar et al., 2021; T. Elmqvist, Alfsen, & Colding, 2008). Framing sustainable, resilient and locally tailored strategies would need a deep knowledge of the local conditions, opportunities, and challenges. As presented in previous paragraphs, GBI and NBS, through the wide range of ecosystem services they provide humans with, are becoming increasingly popular solutions to sustainability challenges. Many authors and research (Almenar et al., 2021; Jansson, 2013; Kenter et al., 2019; Raymond et al., 2017) focused on the identification of the main challenges towards urban sustainability and how GBI and NBS can explicitly and directly support cities in overcoming such challenges. NBS, GBI and, more generally, open public spaces are also explicitly mentioned in the latest report from the JRC of the EU Commission, highlighting their importance in facing urban challenges (Alberti et al., 2019).

Almenar et al., 2021 just recently published a comprehensive study regarding the relation between Urban Challenges (UC), ES and NBS building on the idea that, , NBSs are intrinsically related with the definition of challenges to be face and issues to be solved. In the context of this work, we will refer to the definition of Urban Challenges (UC) made by Almenar et al. 2021, defining 18 challenges based on the review of 312 documents and reports, dividing those in 4 main groups: socio demographic, governance and technological, climate and environmental and health and wellbeing.

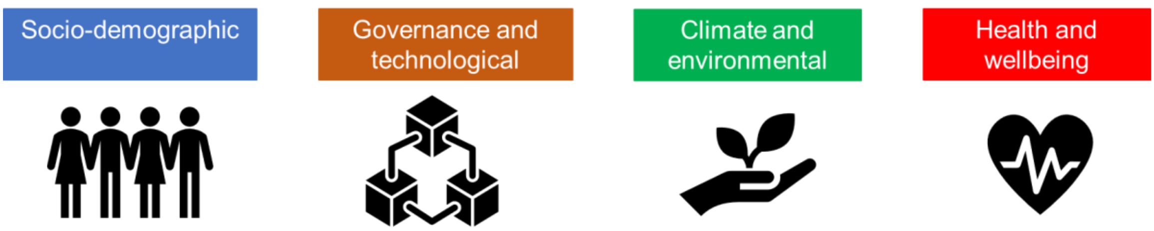


Figure 4-10 Four main groups of urban challenges

Nexus and connections among the listed urban challenges, ES and NBS are various and extensively studied. In their review Almenar et al. 2021 summarized the nexus between UC and ES, highlighting the prevalence of studies relating with health, wellbeing and quality of life in relation with multiple ES, both regulating ES (microclimate regulation and water and runoff regulation) and cultural ES (related with all the range of characteristics of the system that enable physical and experiential and cultural recreation).

Regulating ES health benefits are mostly relevant in terms of regulation of temperature, include lower risk of cardiovascular and heat wave related disease and deaths (Lee, Jordan, & Horsley, 2015; van den Bosch & Ode Sang, 2017), while Cultural ES and specifically the characteristics of the living systems serve as sites of physical activity, which is associated with enhanced health and reduced risk for all-cause mortality and many chronic diseases, i.e obesity, mental health, childrens' health (Barton & Pretty, 2010; Bush et al., 2007; Maas et al., 2009). There is a large number of studies on linkages between park proximity (Ekkel & de Vries, 2017) park attractivity (X. Li et al., 2015; Massoni, Barton, Rusch, & Gundersen, 2018) and physical activity, highlighting the need of carefully distributing, planning and designing GBI in the city. An increasing number of studies is also focusing on GBI potential effects on cognitive decline and prevention of neurodegenerative diseases like Alzheimer's disease (Astell-burt, Navakatikyan, & Feng, 2020; de Keijzer, Gascon, Nieuwenhuijsen, & Dadvand, 2016).

At the same time studies on citizens' wellbeing, and quality of life are focusing on related aspects of GBI usage and benefits. Social cohesion, intended as sense of community, with a focus on trust, shared norms and values, positive and friendly relationships, and feelings of being accepted and belonging can be positively influenced by the presence of GBI as reported by Forrest and Kearns 2001; Sugiyama et al. 2008; De Vries et al. 2013. In all studies social cohesion itself is also positively associated with health and wellbeing.

Climate change and environmental challenges are the most studied groups of urban challenges in relation with ES (Almenar et al., 2021). Case studies and reports mostly highlight the relation among climate mitigation in terms of regulation of chemical conditions, such as GHG emissions and air pollution regulation (Baró et al., 2014; Nowak, Crane, & Stevens, 2006) of existing GBIs. Also, climate mitigation in terms of urban afforestation (converting long-time non-forested land to forest); reforestation (converting recently non-forested land to forest); and avoided deforestation (avoiding the conversion of forests to non-forested land) (Locatelli, 2016) is getting increasing interest.

For what concerns climate adaptation, studies mostly focus on GBI benefits in managing hydrological cycle and water flow and flood regulation (P. Li, Sheng, Yang, & Tang, 2019; Mogollón, Villamagna, Frimpong, & Angermeier, 2016) and regulation of temperature and humidity, producing not just climate but also health related benefits, as already mention in relation with heat wave effects.

Under the challenge 'Built Environment', Almenar et al. 2021 included affordable houses, lack of liveability of public space and urban sprawl. ES can support urban areas in reaching affordable and decent housing through a better use of NBS type 3, such as green roofs and walls, into the built environment, improving microclimate regulation, air purification, but also developing new recreational areas to improve residents' quality of life. The issues of densification and sprawl, briefly mentioned by Almenar et al. 2021, can also largely benefit form Es assessment approach. Indeed, a careful evaluation of the ES cascade within specific areas of the city could provide decision makers with valid argument to propose densification or re-naturing options.

Studies concerning the socio-demographic related challenges, are raising (Anguelovski & Martínez Alier, 2014; Derkzen, Nagendra, Van Teeffelen, Purushotham, & Verburg, 2017; X. Li et al., 2015; Wolff, Schulp, & Verburg, 2015) and their importance is increasingly acknowledged by the academic research, concerning *where, for what and for whom* GBI is currently present and *here, for what and for whom* new NBSs are implemented. Issues of environmental and climate justice are at stake when we discussed about green space distribution and public accessibility (*where*), inclusion of different social groups in the use and the planning of GBI and NBS (*for whom*) features included in the existing GBI or involved in the design of new NBS (*for what*).

The nexus between governance and technological UC and ES/NBS is hard to find in previous literature. Indeed, while the NBS terms intrinsically bring the concept of participatory planning and, financial and governance innovation, NBS projects could, if properly co-planned and designed, support consensus i.e realization of NBS with the support of local stakeholders and public opinion, but they could also generate contrast for competing interests on land use and land use change(Ahern et al., 2014; Schleyer, Görg, Hauck, & Winkler, 2015). Concerning transport and mobility, as another big challenge that cities are facing in the path towards sustainability, even though GBI, green corridors and greenbelts integrated the idea of nature and sustainable mobility no direct nor indirect relation of benefits can be verified (Almenar et al. 2021). Nevertheless, NBS can make an infrastructure more pleasant, which could boost more people to make use of it and using sustainable means of transport, but it can't solve or contribute to solve mobility and transportation issue. Also, the association of GBI and mobility is currently creating issues in some EU Nordic countries, where green areas are transformed into so-called green mobility corridors, de-facto sealing pervious and accessible green areas, to provide those space to mixed mobility uses. Competing functions in this case could hamper the ES provided by such area, sacrificed for infrastructure and mobility purposes.

From this short review, it clearly arose that GBI, ES and NBS have a great role to play in the path towards urban sustainability primarily regarding health and wellbeing, followed by urban climate and environmental challenges. Weaker linkages exist among socio- demographic challenges and ES, while it is becoming evident that properly planned and designed NBS could beneficially contribute to such challenges. Further research in this line would contribute to better understand, assess and further define these links.

4.3.3 URBAN RESILIENCE THROUGH AND OF ECOSYSTEM SERVICES

Despite the growing attention on integrating urban ES into local policies, planning tools and instruments related with climate resilience and disaster-risk reduction (Kaczorowska, Kain, Kronenberg, & Haase, 2016; Woodruff & BenDor, 2016), very little attention has been paid to ensure resilient supply of urban ES over time (McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2015b). While studies of multidisciplinary perspective have been working on urban sustainability and resilience through ES from several perspectives and countries since the beginning of 2000s (Geneletti & Zardo, 2016; Meerow et al., 2004; Romero-Lankao et al., 2016b), securing a resilient flow of ES in cities is receiving science and policy interest in the last decade and predominately in Northern Europe and American countries (Elmqvist et al. 2017, 2018, 2019; McPhearson et al. 2015). In some cases, the discussion about ecosystem health, that ensure the capacity of providing the flow of ES to humans, is still treated as a mere ecological issue. What we need to focus on it is not just *ecology in cities* that focus on designing sustainable buildings, services and processes, providing inhabitants with benefits from the urban and non-urban GBI (Jansson, 2013), but the focus should be, at the same rate, moved to the *ecology of cities* to guarantee that the ecosystems that we rely on and their services will be sustainable and resilient throughout the time (Grimm et al., 2008). Cities will need to plan and manage existing GBIs and new NBSs for sustaining the supply of ES in complex socio-ecological system affected by local and global environmental change. The attention towards ES should be twofold: on the one side cities should seek to include them in urban planning design and management to foster cities resilience in their trajectory towards sustainability, while on the other side cities need to safeguard resilient supply of ES in the long-term to ensure urban human well-being (McPhearson et al., 2015b). For these reasons, ES can be considered a new focal point in a new planning, management and governance practices towards resilience and sustainability (Andersson, Tengö, McPhearson, & Kremer, 2015; Frantzeskaki & Tilie, 2014). Following the suggestion proposed by Meerow and Newell 2019, within this dissertation we will focus on the three main questions around urban resilience: *Resilience of what, to what and for whom?*

Resilience of what?

Resilience and sustainability of ES, being them produce within complex socio-ecological system do not encompass just planning, environment and health-related issues, but crosses also many other social and governance related factors such as people perceptions, participations, and education. In this context, we understand GBI and NBS as the source of local ES, which are then negotiated, regulated and (re-)distributed across urban social-ecological systems (Andersson et al., 2019). The wider social-ecological system in turn is strongly influential in shaping and maintaining the quality and functionality of GBI. To gain a systemic understanding of GBI and to support enhanced availability, accessibility and fair distribution of ES, Andersson et al. 2019 proposed a framework of three interconnected systemic filters: *infrastructures, institutions and perceptions.* These filters are recognized as factors that both affect the capacity of GBI to produce ES and either hinder or facilitate the flow of ES benefits to beneficiaries. While GBI is critical to guarantee the supply of ES, its complex interplay with grey *infrastructures* (different types of housing developments, transportation networks etc.) actors, roles, rights, responsibility and management (*institutions*), as well as specific needs, knowledge, practise, identities (*perceptions*), is critically determining the final uptake of ES benefits by people (Andersson et al., 2019). To enable sustainable flows *of* ES benefits, urban policies must acknowledge this fundamental character of urban ES benefits being deeply co-produced by natural and human assets (Ernstson, 2013; Langemeyer & Connolly, 2020).

Furthermore, policies must build resilience around the factors that enables the supply of ES benefits (McPhearson et al., 2015) and do this in the light of diverse and changing *demands* for ES benefits in the future (Langemeyer & Connolly, 2020).Biggs et al. 2012, identified seven generic policy-relevant principles (Fig. 4-11) for building resilience sustaining ES in socio-ecological systems: (P1) to maintain diversity and redundancy, (P2) to manage connectivity, (P3) to manage slow variables and feedbacks, (P4) to foster an understanding of complex adaptive systems, (P5) to encourage learning and experimentation, (P6) to broaden participation, and (P7) to promote polycentric governance systems.

Figure 4-11 Seven principle for building resilience – sustaining ES in socio-ecological systems (Biggs et al. 2012)

The adaptation of these principles to the urban realm and the implementation into urban policies and strategies would support to enable the transition to desirable trajectories in terms of urban ES resilience. The integration of ES resilience principles into policies and planning approaches can work as a lens for identifying leverage points for unlocking the flows of ES from nature to humans – under potential future conditions as well as current (Biernacka and Kronenberg 2018; Elmqvist et al. 2019).

Resilience to what?

Resilience research and practices are too often narrowly focussed on single external drivers of change, for example climate change, and tend to overlook the combination, interaction, and feedbacks between different external drivers of change and inherent systems' dynamics.

The relation of urban resilience with the concepts of adaptation and preparedness to constant changes and possible disturbances of the system, created linkages, with climate change adaptation and disaster risk reduction (Meerow & Newell, 2019). While this approach boosted the uptake of climate-proof planning and accelerated the idea of scenario planning to adapt to climate change in the forthcoming future, on the other side *resilience to* other disturbances, possible changes and slow variables have been left behind. Cities are failing in considering resilience of the whole SES to diverse changes and disturbances, not considering possible demographic (e.g. aging, shrinking population, gender or other vulnerable groups issues), economic (e.g. tourism increase or immediate decrease, housing issues, financial crisis, etc.), or social issues (social breakdown, polarization, etc). As an example of the climate-narrowed vision of resilience, the resilience strategy of New York City developed within the 100 cities programme of the Rockefeller foundations, developed a comprehensive and well- designed strategy to face climate change and its potential consequences over different sectors and population, but did not include any other potential driver of change (City of New York, 2013). While the city council managed to include and foresee possible risks related with climate change impacts (e.g. sea level rise, increased precipitation, high average temperature) on different socio-economic sectors (healthcare, community response, economic recovery) infrastructures and services (utilities, telecommunication, transportation and parks) and environmental compounds (water, coastal protection), the city did not consider other potential risks thus limiting urban resilience to climate change resilience. While climate change is likely to alter the physical capacity of urban GBI to provide ES (Runting et al., 2017), it might also interact with an ageing society as well as cause feedbacks on people's *perceptions* that both alter ES needs and preferences (Derkzen et al. 2017; Wolff et al. 2015).

At the same time, the raising of the COVID-19 pandemic clearly showed that unexpected external driver of change can suddenly take place in complex socio ecological system, setting new priorities and claiming for behavioural, societal, and economic change. The pandemic is the perfect example to reflect on the multifaceted nature of ES cascade and flows and their resilience into the cities. While ES supply and capacity were not or positively affected by the COVID-19, due to less pollution and usage, most of the cities decided to close access to Urban Green Spaces, in the exact moment where ES, mostly CES, were needed at the most. The changing perceptions of *people* regards their need of benefits deriving from CES created a new form of ES demand, more conscious, proactive and participated (Fisher and Grima 2020). Cities started to adapt themselves in terms of new *institutions and practices* regarding the use of such areas. Resilience to pandemic, among other mentioned drivers of change is and will be a crucial issue for present and future and management of urban areas, where GBIs and new NBS can play a decisive role.

Resilience for whom?

Building ES resilience in cities also requires ensuring the equal distribution of GBI benefits to different groups of the society, while those benefits are often unequally distributed among different social groups (Ibes 2015; Kabisch et al. 2016; Rutt and Gulsrud 2016)), with respect to socio-economic, gender, age and ethno-racial characteristics, and particular barriers are given that exclude certain social groups from the flow of benefits that GBI provide (Wright, Zarger, and Mihelcic 2012). Exposure and vulnerability to diverse burdens and climate hazards are generally unequally distributed across neighbourhoods and socioeconomic population groups (see, for instance, Harlan et al. 2006; Moreno-Jiménez et al. 2016).Urban GBIs can play a pivotal role in mitigating environmental burdens, contributing to climate change adaptation, increasing public health and social cohesion, and ultimately, creating more sustainable and liveable cities (Baró, Calderón-Argelich, Langemeyer, & Connolly, 2019; Tzoulas et al., 2007). Ensuring the distribution of GBI and NBS benefits to different groups of the society, through appropriate policy framings and participation in decision making as well as the acknowledgment of diverging societal needs and preferences (Langemeyer and Connolly, 2020) would require appropriate methods and governance that take into account potential changes in citizens' desires or needs, as well the future distribution of benefits among different social groups.

To ensure such just distribution, cities would first need to map and assess the current distribution and flow of ES benefits within the city focusing on the distributive dimension of urban environmental justice and ES, i.e., who benefits most and who remains excluded from access to the benefits of UGI in cities (Ernstson, 2013), and more specifically, on the socio-spatial inequalities related to the provision of ES. Findings indicated that areas with higher population density, lower incomes, and a greater share of minority residents had inferior access to public recreational programming. Nevertheless, most of this study come from the US or UK, and not many studies regarding the topic have been carried out in southern Europe and more specifically in Italy.

Also, in line with the principle mentioned in previous paragraph (*resilience to what?*) forecasting potential changes in citizens' desires or needs, as well the future distribution of benefits among different social groups, would ensure a just and long-lasting distribution of ES benefits in the city. Reflecting upon the needs of an aging society, for instance would largely support planners in modifying the design of urban green areas, reflecting on their needs and perceptions.

4.4 ECOSYSTEM SERVICES IN PLANNING: CONCEPTUAL AND METHODOLOGICAL FRAMEWORK

The proposed approach builds on the so-called 'ES cascade model' (Potschin and Haines- Young, 2011 based on previous frameworks such as de Groot et al., 2002) which is widely used in numerous global, national and subnational ES assessments such as TEEB (2011) or MAES (Maes et al., 2016) and allows methodological integrations coming from the ENABLE framework proposed by Andersson et al.2019 and from the seven principle for resilience introduced by Biggs et al., 2012.

The ES cascade framework conceptual model describes key steps in the 'production chain', linking ecosystems to socio-ecological systems through the flow of ecosystems services, also highlighting the role of ES co-production. The framework highlights the relationships between ecosystem structures (supply) and functions (capacity), services and benefits (flow) that people (demand) gain from ecosystems, which are finally valued either in monetary or nonmonetary dimensions. It hence emphasizes that ES exist only in relation to demand. It is worth noting that in the ES literature there are still different approaches and terminologies for framing these components, especially regarding ES flow and demand (Villamagna et al., 2013; Wolff et al., 2015).

ES supply can be considered as biophysical quantification of ES (Haines-Young & Potschin 2010) or *the full potential of ecological functions or biophysical elements in an ecosystem to provide a potential ES, irrespective of whether humans actually use or value that function or element currently* (Tallis, Taylor, Sinnett, & Freer-Smith, 2011), and it is strictly linked with the ES capacity as *the long-term potential of ecosystems to provide services appreciated by humans in a sustainable way, under the current management of the ecosystem* (Schröter et al., 2014). On the other side several authors argued on the definition and related assessment of ES flow and demand and recent conceptualisations of ES have highlighted the need for distinguishing the capacity to provide services and the actual use beneficiaries make of them. Some other authors (Burkhard, Kroll, Nedkov, & Müller, 2012) have framed ES demand as direct use or final consumption but, within this work, we will refer to ES flow as the actual use of ES that occurs at a precise time and location, while ES demand is the expression of the individual preferences for specific attributes of the service, such as biophysical characteristics, location and timing of availability and should be framed based on societal desires and needs (Villamagna et al., 2013). It's worth highlighting that the demand may well be larger than the actual ES flow and that demand assessment would assume diverse meaning depending on the typology of ES (Wolff et al., 2015). Indeed, supporting or habitat services are not considered to have a direct demand, while a risk reduction approach is commonly applied to quantify demands for regulating ES. Within this work, demand indicators of regulating ES refer to existing normative values or regulation (e.g., air pollution levels for air purification) or current monitored values (PM10 concentration values), considering the vulnerability or exposure of society to these pressures. On the other side, for most cultural ES, demand is normally assessed using population needs, depending on their socio-economic characteristics, people's stated preferences, expectations or values, usually complemented with accessibility levels to ES providing areas such as parks or other green spaces (Wolff et al., 2015). While studies on this topic start to raise, research on ES diversified demand, citizens' perception and co-production are still lacking. Assessing and evaluating citizens' demand and perception, together with a better knowledge on the quality and the distribution of urban ecosystems, would largely contribute to raise awareness on people needs in terms of ES and related GBI in the city and could support planners and decision makers when making decision on urban densification.

4.4.1 ASSESSING ES SUPPLY AND DEMAND IN COMPLEX SOCIO-ECOLOGICAL SYSTEMS

In the proposed conceptual framework presented in Fig 5.9, we integrate the ES cascade models with three concepts coming from Andersson et al. 2019 that could support a wider understanding of the relevance of policy making into the system. Within this dissertation, we will refer to: (a) infrastructure as the built and green and blue infrastructures limiting or enabling the (local) availability of ES, affecting ES supply and capacity; (b) institutions, including urban governance systems (policy and planning) that determine, access to and control over ES (Berbés-Blázquez et al., 2016) and shape urban ecosystems (structure, functions and perceived good and benefits), and (c) people's perceptions, understood as the subjective and context-dependent definition of ES benefits and their importance, thus strictly related with ES demands for such ES (Langemeyer et al. 2019, Juntti and Lundi, 2017; Biernacka and Kronenberg, 2019). ES provision requires all of these 'filters' (Andersson et al., 2019) operating at once in order to achieve a just outcome.

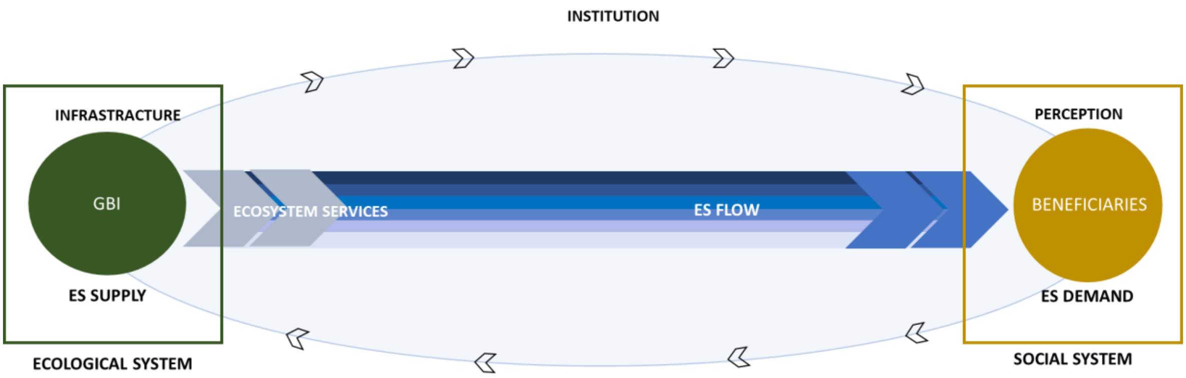


Figure 4-12 Ecosystem-based conceptual framework. Author elaboration based on the ES cascade model and the ENABLE filters embedded in Socio Ecological System

Building on Fig 4-12, three, this work will address three knowledge gaps on three diverse recognized issues:

- The supply- demand gap for Regulating Ecosystem Services (RES)
- The supply demand gap for Cultural Ecosystem Services (CES)
- The resilience gap for urban ES

The proposed conceptual methodological framework will be tested in two diverse case studies. Specifically, we will test the methods for mapping and assessing RES and CES supply and demand gaps in the city of Bologna, as the main case study of the thesis. As for the resilience gap, the proposed approach will be tested in the City of Barcelona. Indeed, Barcelona has been one of the pioneer cities in Europe concerning the integration of ES into planning and can be considered a lighthouse example for other cities in Europe. Moreover, the author had the possibility to closely interact with the city Council that is working on the integration of ES into its resilience strategy, getting the possibility of applying the methodology in a participatory context with local relevant stakeholders.

4.4.1.1 THE 'SUPPLY-DEMAND' GAP FOR REGULATING ES (RES)

An increasing body of knowledge exists on the provision of RES (supply side) at different scales, while studies are just raising about the mismatches on the supply and demand side. Thanks to the emergence of modelling tools and high-resolution spatial datasets, rapid progress has been made over the past decade on evaluating and integrating ecosystem services into planning. Ecosystem service models provide important tools to facilitate national and regional decision-making by assessing service trade-offs and synergies across multiple sectors under diverse management scenarios (Guerry et al., 2015; Maes et al., 2013), moving away from single-goal oriented approaches. The Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES) has reviewed and summarized existing modelling tools to guide regional, global and thematic assessments as well as outlining best-practices for policy-makers in the use of these tools (IPBES, 2016). However, guidance on how and when ecosystems and their services should be managed to deliver on specific and/or multiple benefits to citizens remains poorly articulated and difficult for policymakers to incorporate into local policies and urban plans. To better support urban planning and to develop ES-based decision-making process able to prioritize areas and type of intervention, it is crucial to spatially identify which areas present higher mismatches in ES supply and demand, and to spatially assess the flow of the benefits from different areas of the city. The resulting ES maps offer important tools for decision makers and institutions and are also important to assess spatial trade-offs among ES (Martnez-Harms & Balvanera, 2012).

Building on the conceptual approach showed in Fig. 4-12, the methodological approach proposed to map and assess supply and demand mismatches of run-off regulation, air filtering (PM10 regulation) and global climate regulation (carbon sequestration) builds on existing literature on the topic (Baró, Haase, Gómez-Baggethun, & Frantzeskaki, 2015; Chen, Jiang, Bai, Xu, & Alatalo, 2019; Larondelle & Lauf, 2016; Pauleit & Duhme, 2000; Vihervaara, Mononen, Nedkov, & Viinikka, 2018) and it has been developed and adapted to the case study of the city of Bologna, then replicable in dense European middle and large city. Specifically, Chapter 5 will include the detailed description of the methods and tools used to compute RES supply, demand and possible mismatches and to map their distribution, explaining how these data have been either calculated or transposed into a GIS environment, producing, as a final output, maps of the city that will allow to classify and compare different urban sectors, thus identifying intervention priorities, opportunities and challenges. In the context of this work, the most recent data available have been used and the assessment does not include future change and fluctuations in ES demand and supply. Those possible shifts and fluctuations will instead be considered in the participatory methods proposed in Section Chapter 7 focusing on stakeholders and experts' opinion to assess ES resilience over the time.

4.4.1.2 THE 'SUPPLY-DEMAND' GAP FOR CULTURAL ES

Cultural Ecosystem Services and related flows of benefits – mostly related with health and personal wellbeing - are usually included under non-consumptive direct use values (Millenium Ecosystem Assessent, 2005) and despite the increasing recognition of their value into citizens' quality of life they still suffer from poor quantification and integration in management and decision making and planning processes (Milcu, Hanspach, Abson, & Fischer, 2013). Being characterised as *"intangible", "subjective" and "difficult to quantify"* (Daniel et al., 2012; Hegetschweiler et al., 2017) capitalizing on the societal relevance of CES would largely help to address real-world problems (Milcu et al., 2013).

Whereas mapping the location and quantifying the benefits of regulating services can be straightforward, relying on modelling and assumption and taking into consideration the generated degree of errors, precisely delineating the boundary of the area and the quantification of 'intangible' cultural ecosystem services could be more challenging. Indeed, cultural services strongly depend not only on the characteristics and features of the infrastructure of the GBI (ecological and supply side of the ES cascade model previously presented), but also on perceptions and expectations of the respective users that interact with the existing GBI (social and demand side of the overmentioned model). For this reason, *considerable conceptual and technical work may be needed to represent and model the complex socio-ecological relationships that define and constrain a given cultural eco-system service adequately* (Daniel et al., 2012). People are critical to CES production and valuation as both occur at least partly in the mind of the observer (Dickinson & Hobbs, 2017) and CES are not ''*a priori products of nature that people utilise for a particular benefit to wellbeing – but rather as relational processes and entities that people actively create and express through interactions with ecosystems*'' (Fish, Church, & Winter, 2016). CES are also strongly place-based as different sites, even presenting similar characteristics and features, would generate its own unique experiences, and related benefits, for users (Satterfield, Gregory, Klain, Roberts, & Chan, 2013). Nevertheless, it is worth noticing that co-production could be affected by different socio-cultural characteristics of the population (income, ethno-racial characteristics, age, gender, (dis)ability, and other axes of difference) defining vulnerable groups of users that are not always able to make use of GBI due to the uneven accessibility of urban greenspace (J. R. Wolch, Byrne, & Newell, 2014). Since the benefits generated by CES are strictly related with the access to and the activities that beneficiaries performed in a specific place and time, ecosystem services have the potential to generate similar benefits across all segments of the human population. However, because ecosystem services (in general) and cultural services (in particular) are not evenly distributed in urban areas, differential access to and use of GBI can exacerbate exiting disparities (Jennings, Larson, & Yun, 2016). Urban GBI are ecosystems ''*deeply situated in the functioning of society*'' (Haase et al., 2014). As such, the CES co-production and related mapping and assessment assume a particular relevance in urban ecology and planning research (Dickinson & Hobbs, 2017). Cities are complex adaptive socio-ecological system including various socio-cultural and demographic features, and the interaction between the social and the ecological systems happens in the urban GBI and represent human perceptions and experiences of nature in the city. For this reason, GBI is a rich and challenging research areas that uses a variety of concepts, methods, and tools to capture complexity of urban system. Nevertheless, CES valuation is assuming a great importance as citizens actions, practices and participation into urban decision-making processes is increasingly gaining attention through participatory and bottom-up process of around GBI (Andersson, Tengö, McPhearson, & Kremer, 2015; Colding & Barthel, 2013). Thus, understanding CES as co-produced and co-valued services distributed by the existing GBI to the population would largely contribute to improve current GBI management and improvement and to develop inclusive and multifunctional urban NBS in the future. Researchers have used a variety of monetary and non-economic approaches to assess the 'intangible' and valuate CES supply and demand including GBI quality and accessibility analysis, expenditures or willingness to pay for pre-defined services(van Berkel & Verburg, 2014), travel costs and experience valuation (Ruiz-Ballesteros & Cáceres-Feria, 2016), surveying perceptions through offline and online questionnaires (Subiza-Pérez, Hauru, Korpela, Haapala, & Lehvävirta, 2019), stakeholder workshops (Schubert et al., 2018) or experts' interviews, visitor observations, etc. Nevertheless, regardless the method, it is important to take *CES supply, demand and flow* into account when measuring ecosystem services, in order to more accurately ascribe changes to the potential of the ecosystem to provide services and/or to changes in human inputs or demand (Albert et al., 2016). There is little information on ES needs and perceptions (demand side) in urban areas, and whether this demand matches or not the capacity of urban ecosystems to deliver ES (Haase et al., 2014). Vulnerabilities and capabilities of people and groups of people should be considered and integrated into ecosystem services assessments, as these influence which ecosystem structures are eventually turned into benefits and gives important insights into the environmental justice related to the distribution of ecosystem benefits (Pham, Apparicio, Seguin, Landry, & Gagnon, 2012; Rutt & Gulsrud, 2016; Wen, Albert, & Von Haaren, 2020; Wright Wendel et al., 2012). The developed methods, further presented in Chapter 6, will be applied to different categories of CES – physical recreation, cultural recreation, cognitive development and social relations and cohesion. Specifically, the role of perceptions and co-production will be explored at city level, using the city of Bologna as case study.

Within this work, we will focus mainly on 4 CES related with urban outdoor recreation:

1. Physical recreation: Physical and experiential interactions with natural environment (CICES V5.1), and outdoor activities relating to the local environment as form of sports or active mobility (adapted from Kandziora, Burkhard, and Müller 2013) – cycling, hiking, trailing, swimming, etc.

2. Experiential and Cultural recreation: Physical and experiential interactions with natural environment that don't include active physical activities or sport, outdoor activities or tourism relating to the local environment including leisure. In this dissertation this includes also the aesthetic benefits as intangible value that is measured by "*man's search for pleasure, pleasantness, discovery that takes place in his free time and outside the space in which he lives*" (Vasiljevic & Gavrilovic, 2019).

3. Cognitive development and educational value: Intellectual and representative interactions with natural environment (CICES 5.1). Environmental education based on ecosystems and landscape features - i.e outdoor schools, urban forests and allotment gardens are often used for environmental education purposes (adapted from Kandziora, Burkhard, and Müller 2013) facilitating cognitive

coupling to seasons and ecological dynamics in technological and urbanized landscapes (Gómez-Baggethun & Barton, 2013)

4. Social relations and cohesion: Attachment to green spaces in cities can also give rise to other important societal benefits, such as social cohesion, promotion of shared interests, and neighbourhood participation. It refers to the elements of living systems used for entertainment by a group of people (adapted from CICES 5.1), including access to mates and being loved (Wallace, 2007).

To map and assess these 4 CES in the urban realm we would then analyse both the supply and the demand size, as show in Fig. 4-13.

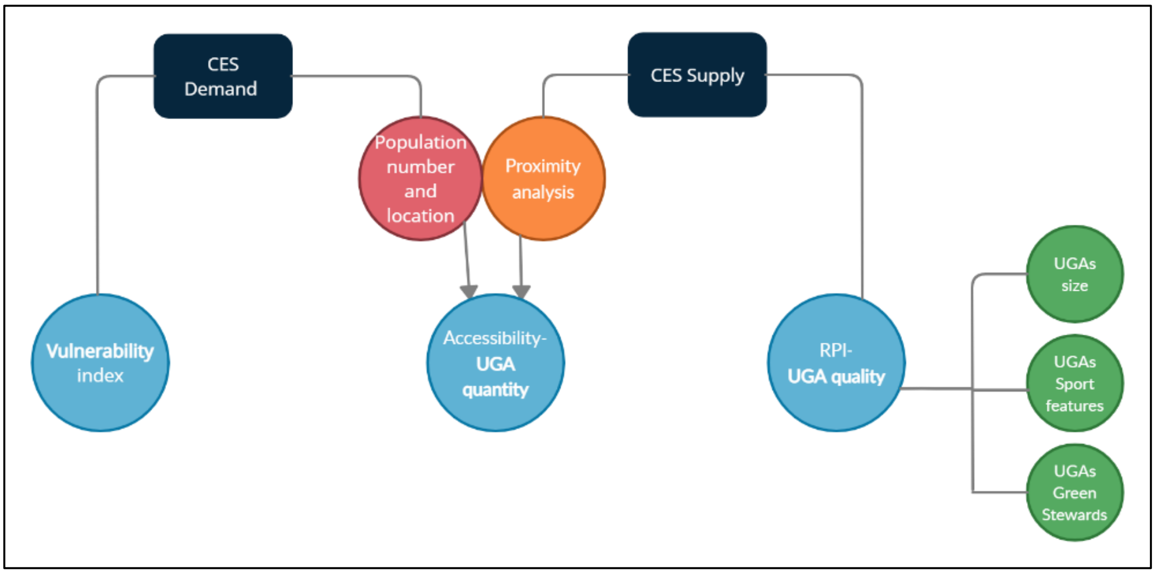


Figure 4-13 Workflow to assess CES supply and demand

This framework builds on existing literature including the assessment of new features and methods in assessing and mapping the supply and demand:

<u>CES Supply assessment</u>: Very different methodologies have been developed and used so far to assess potential CES supply. Several studies mapped habitat, structural or even species diversity while most of them used data about the size or shape of the green space, according to Hegetschweiler et al. 2017. The supply and distribution of green spaces in the city, district, or neighbourhood was addressed by many authors, using data on facilities for sport, play or relaxation, though only their presence or quantity have usually been taken into account (e.g. Camps-Calvet et al. 2016; Hamstead et al. 2018; Ye, Hu, and Li 2018). Nevertheless, despite the quality of such features is recognized to be a crucial factor, most of those studies tend to neglect quality assessment. Also, there is consensus regarding

proximity and accessibility as crucial indicators (Hegetschweiler et al., 2017) for the urban greenspace benefits as an essential pre-condition to enable the flow of CES from GBI to final users, and several methods and tools have been developed to evaluate accessibility and proximity of urban GBI. The supply is intended here as the potential of the urban GBI for urban outdoor recreation and education activities and will be calculated through proximity/accessibility analysis and through the development of the Urban Recreation Potential Indicator (URPI). Proximity analysis of the Urban Green Areas will be assessed through a network analysis from UGA access points, defining hierarchical level of UGA (see e.g. Grunewald et al. 2017; Quatrini et al. 2019; La Rosa 2014). On the other side, the URPI build on existing literature (Cortinovis, Zulian, & Geneletti, 2018; Paracchini et al., 2014) to develop an urban-tailored indicator for assessing the role of GBI qualities and features in distributing and making available CES. While Recreation potential normally refers to degree of naturalness, natural protected areas and water we claim that outdoor nature-based recreation in urban areas may be influenced by namely: size of the GBI, sport features quality and Urban Green Stewards (UGS) operating in the urban GBI. Although quality may be more important than quantity in certain cases, larger areas with more natural vegetation might offer more or deeper restoration than small areas with little vegetation (Ekkel & de Vries, 2017; Ibes, 2015), thus influencing experiential and cultural related services. At the same time, for stimulating physical activity, that enable most of CES related health benefits, the presence of sport features may influence the activity (Hegetschweiler et al., 2017) and the target groups addressed (Ekkel & de Vries, 2017; Gong, Zheng, & Ng, 2016; Kabisch & van den Bosch, 2017). Last, facilitating social cohesion and educational services could require not just proper designed UGA, but also actors able to facilitate the flow and the co-production of such services including also diverse social and cultural groups. Environmental organizations, associations or community initiatives that implement a wide range of activities in UGAs (e.g. educational and cultural activities, green maintenance, urban farming, social activities, etc.) (Andersson et al., 2017; Camps-Calvet et al., 2016; Ferreira, Barreira, Loures, Antunes, & Panagopoulos, 2020) can be addressed as "green stewardships" that would largely support the flow of benefits also to groups of population that otherwise may be excluded. For this reason, within this work, we will consider size, sport features quality and Green Stewardship role for the assessment of UGA potential to enable physical recreation, experiential recreation, educational services and social cohesion. The main hypothesis here lies on the idea that tailored sport features (e.g. ethnic or age-sensitive design) and local Urban Green Stewards (e.g. local no profit association, single citizens actions, cultural association, public association, etc.) active on the urban GBI can act as powerful enablers of specific CES flow in the city, i.e physical, experiential and cultural recreation and education and cognitive value, guaranteeing a wide range of benefits to different target population. The methods and tools for CES supply assessment are presented in Chapter 6.

CES Demand assessment: while the demand for CES strictly depend on the needs of local population and could be assessed again through qualitative (i.e questionnaire, revealed preferences, survey) and quantitative (number of inhabitant) methods, within this work we focus on the distributive dimension of justice and CES, considering people needs in terms of their recognized vulnerability. Indeed, diverse economically, socially, and racially disadvantaged social groups, may not just be excluded from the flow of ES, but also present diverse need (Bertram & Rehdanz, 2015; Fischer & Eastwood, 2016)(Bertram & Rehdanz, 2015; Fischer et al., 2018). Building on Baró et al. 2019; Ernstson 2013; Jennings, Larson, and Yun 2016, we will look at distributional inequalities related to the provision of CES in the city.

CES Supply and demand: Understanding the dynamic interaction between user needs and the strategies adopted by managers to meet these needs may be an important driver for managing ecosystem service delivery (Fu et al., 2020). Within this work we will verify the distributional aspects of CES in the city, first assessing accessibility to UGA by the overall population, and then looking at distributional justice aspects, adding vulnerabilities of the population as a further proxy of differentiated needs in terms of CES demand.

With the proposed framework, this works aim at addressing the research gaps identified in the agenda for urban green spaces in Europe highlighted by (Rutt & Gulsrud, 2016), specifically regarding the development of spatial analyses based on a new and pluralistic notion of quality (including sport features and local association in the assessment of CES supply) and relating this with CES distribution dimension of justice in the city. This methodological framework will be applied and tested to assess spatial mismatches and distributive justice in the city of Bologna and will be presented in Chapter 6.

4.4.1.3 THE RESILIENCE GAP FOR URBAN ES

While most studies are working on the mapping and assessing current ES in urban GBI and UGAs, as presented in previous sections, only a few discuss the impacts of possible external drivers of change, e.g. land use change, increase of human pressure, climate change of inherent drivers of change, e.g. demographic social or economic changes within the urban socio-ecological system (SES). These drivers of change can affect not only the supply of RES and CES, but can also heavily impact ES demands, changing the behavioural patterns in open space users (Unt & Bell, 2014). As presented in previous paragraph, the need for building urban resilience has increasingly gained attention in the last decade both in science, and in practice, and it has received substantial policy interest (Elmqvist et al., 2019; Jansson, 2013; McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2015a). Tailored and adaptive policies and interventions need to reduce resilience of the barriers to equitable access and distribution of ES benefits and to build and increase resilience around the factors that enable the flow of ES benefits over time (Frantzeskaki, 2019; McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2015b). Furthermore, planners and decision makers are continuously dealing with uncertainties and policies – *devised not to be optimal for a best estimate future, but robust across a range of plausible futures* (Walker, Rahman, & Cave, 2001) – that should be able to adapt in the light of diverse and changing supply and demands for ES benefits in the future(Langemeyer & Connolly, 2020). However, from a practical perspective, while mathematical modelling and machine learning approach can support predictions of plausible future, building resilience around urban SES is far from obvious. Within this work we believe that transforming or guiding cities towards desired and sustainable futures, where ES supply matches ES demands (*cf.* Baró et al. 2016; Villamagna, et al. 2013) requires a better integration of resilience thinking in urban policies. Building upon the adapted ES cascade framework presented in Fig 5.9, we have included in the framework potential drivers of change (e.g. climate, political or socio demographic drivers) and the 7 Biggs principle for resilience as a useful lens to sustain ES benefits under diverse future scenarios as presented here below in Fig.4-14.

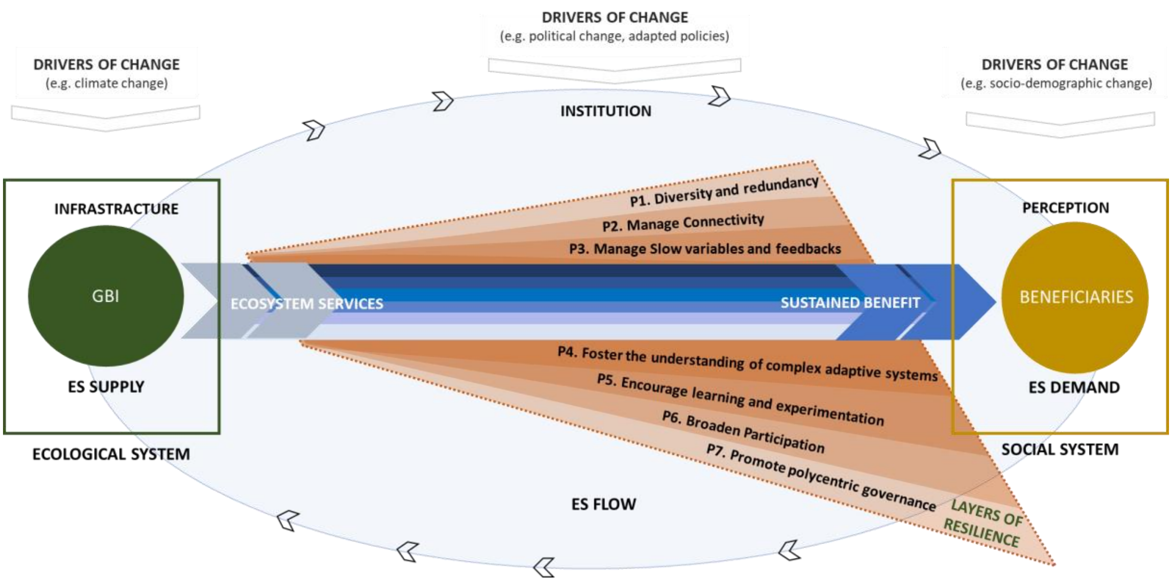


Figure 4-14 Biggs resilience principles to enable the GBI capacity in providing ES and unlock the flows of benefits to beneficiaries, under different drivers of changes.

The tailoring of the Biggs principles to the urban realm would support the analysis of resilience thinking into current policies framework. Departing from this analysis, our methodological framework proposes to develop a participatory approach with local stakeholders to discuss possible future scenario considering various drivers of change (e.g. climate change, demographic change or political change) (Nelson et al. 2005). The scenario would trigger the discussion towards ES resilience over the time and towards the development of adaptive policy options to sustain ES under various drivers of change (Sauter et al., 2019). The real case application of this methodological framework took place in Barcelona and the related results will be presented in Chapter 7.

LIST OF REFERENCES

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, *125*, 254–259. https://doi.org/10.1016/J.LANDURBPLAN.2014.01.020

Alberti, V., Alonso Raposo, M., Attardo, C., Auteri, D., Ribeiro Barranco, R., Batista E Silva, F., … Zulian, G. (2019). *The Future of Cities: Opportunities, challenges and the way forward*. https://doi.org/10.2760/375209

Almenar, J. B., Elliot, T., Rugani, B., Philippe, B., Gutierrez, T. N., Sonnemann, G., & Geneletti, D. (2021). Nexus between nature-based solutions, ecosystem services and urban challenges. *Land Use Policy*, *100*.

Andersson, E., Langemeyer, J., Borgström, S., McPhearson, T., Haase, D., Kronenberg, J., … Baró, F. (2019). Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems. *BioScience*, *69*(7), 566–574. https://doi.org/10.1093/biosci/biz058

Andersson, E., Tengö, M., McPhearson, T., & Kremer, P. (2015). Cultural ecosystem services as a gateway for improving urban sustainability. *Ecosystem Services*, *12*, 165–168. https://doi.org/10.1016/j.ecoser.2014.08.002

Anguelovski, I., & Martínez Alier, J. (2014). The "Environmentalism of the Poor" revisited: Territory and place in disconnected glocal struggles. *Ecological Economics*, *102*, 167–176. https://doi.org/10.1016/j.ecolecon.2014.04.005

Astell-burt, thomas, Navakatikyan, M. A., & Feng, X. (2020). Urban green space, tree canopy and 11-year risk of dementia in a cohort of 109,688 Australians. *Environment International*, *145*.

Baró, F., Calderón-Argelich, A., Langemeyer, J., & Connolly, J. J. T. (2019). Under one canopy? Assessing the distributional environmental justice implications of street tree benefits in Barcelona. *Environmental Science and Policy*, *102*(June), 54–64. https://doi.org/10.1016/j.envsci.2019.08.016

Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D. J., & Terradas, J. (2014). Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. *Ambio*. https://doi.org/10.1007/s13280-014-0507-x

Bartesaghi Koc, C., Osmond, P., & Peters, A. (2017). Towards a comprehensive green infrastructure typology: a systematic review of approaches, methods and typologies. *Urban Ecosystems*, *20*(1), 15–35. https://doi.org/10.1007/s11252-016-0578-5

Barton, J., & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health- A multi-study analysis. *Environmental Science and Technology*, Vol. 44, pp. 3947–3955. https://doi.org/10.1021/es903183r

Biernacka, M., & Kronenberg, J. (2018). Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. *Urban Forestry & Urban Greening*, *36*, 22–33. https://doi.org/10.1016/J.UFUG.2018.09.007

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S. B., Cundill, G., … West, P. (2012). Toward Principles for Enhancing the Resilience of Ecosystem Services. *Ssrn*. https://doi.org/10.1146/annurev-environ-051211-123836

Biggs, R., Schlüter, M., & Schoon, M. L. (2015). Principles for building resilience: Sustaining ecosystem services in social-ecological systems. In *Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems*. https://doi.org/10.1017/CBO9781316014240

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics*, *29*(2), 293–301. https://doi.org/10.1016/S0921-8009(99)00013-0

Breuste, J. H., & Artmann, M. (2015). Allotment Gardens Contribute to Urban Ecosystem Service: Case Study Salzburg, Austria. *Journal of Urban Planning and Development*, *141*(3), 1–10.

https://doi.org/10.1061/(asce)up.1943-5444.0000264
Brunner, S. H., & Grêt-Regamey, A. (2016). Policy strategies to foster the resilience of mountain social-ecological systems under uncertain global change. *Environmental Science and Policy*, *66*, 129–139. https://doi.org/10.1016/j.envsci.2016.09.003

Burkhard, B., Kroll, F., Nedkov, S., & Müller, F. (2012). Mapping ecosystem service supply, demand and budgets. *Ecological Indicators*, *21*, 17–29. https://doi.org/10.1016/j.ecolind.2011.06.019

Bush, C. L., Pittman, S., McKay, S., Ortiz, T., Wong, W. W., & Klish, W. J. (2007). Park-based obesity intervention program for inner-city minority children. *The Journal of Pediatrics*, *151*(5), 513–518. https://doi.org/10.1016/j.jpeds.2007.04.008

Childers, D. L., Cadenasso, M. L., Morgan Grove, J., Marshall, V., McGrath, B., & Pickett, S. T. A. (2015). An ecology for cities: A transformational nexus of design and ecology to advance climate change resilience and urban sustainability. *Sustainability (Switzerland)*. https://doi.org/10.3390/su7043774

City of New York. (2013). *A Stronger, more resilient New York*.

Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. xiii + 97pp

Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation*, *141*(1997), 350–352. https://doi.org/10.1016/j.biocon.2007.12.020

Crossman, N. D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., … Maes, J. (2013). A blueprint for mapping and modelling ecosystem services. *Ecosystem Services*, *4*, 4–14. https://doi.org/10.1016/j.ecoser.2013.02.001

Davies,C., Hansen, R., Rall, E., Pauleit, S., Lafortezza, R., De Bellis, Y. Santos, A. Tosics, I. (2015). Technical report GREENSURGE, 2015 Green Infrastructure Planning and Implementation - The status of European green space planning and implementation based on an analysis of selected European city-regions

de Groot, R. S., Alkemade, R., Braat, L., Hein, L., & Willemen, L. (2010). Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity*, 7(3), 260–272. https://doi.org/10.1016/j.ecocom.2009.10.006

de Keijzer, C., Gascon, M., Nieuwenhuijsen, M. J., & Dadvand, P. (2016). Long-Term Green Space Exposure and Cognition Across the Life Course: a Systematic Review. *Current Environmental Health Reports*, *3*(4), 468–477. https://doi.org/10.1007/s40572-016-0116-x

De Vries, S., van Dillen, S. M. E., Groenewegen, P. P., & Spreeuwenberg, P. (2013). Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Social Science and Medicine*, *94*, 26–33. https://doi.org/10.1016/j.socscimed.2013.06.030

Dearing, J. A., Wang, R., Zhang, K., Dyke, J. G., Haberl, H., Hossain, M. S., … Poppy, G. M. (2014). Safe and just operating spaces for regional social-ecological systems. *Global Environmental Change*, *28*(1), 227–238. https://doi.org/10.1016/j.gloenvcha.2014.06.012

Derkzen, M. L., Nagendra, H., Van Teeffelen, A. J. A., Purushotham, A., & Verburg, P. H. (2017). Shifts in ecosystem services in deprived urban areas: Understanding people's responses and consequences for well-being. *Ecology and Society*, *22*(1). https://doi.org/10.5751/ES-09168-220151

Eggermont, H., Balian, E., Azevedo, J. M. N., Beumer, V., Brodin, T., Claudet, J., … Le Roux, X. (2015). Nature-based solutions: New influence for environmental management and research in Europe. *Gaia*, *24*(4), 243–248. https://doi.org/10.14512/gaia.24.4.9

Ekkel, E. D., & de Vries, S. (2017). Nearby green space and human health: Evaluating accessibility metrics. *Landscape and Urban Planning*, *157*, 214–220. https://doi.org/10.1016/j.landurbplan.2016.06.008

Elmqvist, T., Alfsen, C., & Colding, J. (2008). Urban Systems. *Encyclopedia of Ecology*, (June), 3665–3672. https://doi.org/10.1016/b978-008045405-4.00364-5

Elmqvist, T., Andersson, E., Gaffey, O., & McPhearson., T. (2017). Development: Sustainability and resilience differ. *Nature*, *546*, 352.

Elmqvist, Thomas, Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., … Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability*, *2*(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Elmqvist, Thomas, Bai, X., Frantzeskaki, N., Griffith, C., Maddox, D., McPhearson, T., … Watkins, M. (Eds.). (2018). *Urban Planet*. https://doi.org/10.1017/9781316647554

Ernstson, H. (2013). The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes. *Landscape and Urban Planning*, *109*(1), 7–17. https://doi.org/10.1016/j.landurbplan.2012.10.005

Escobedo, F. J., Giannico, V., Jim, C. Y., Sanesi, G., & Lafortezza, R. (2019). Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? *Urban Forestry and Urban Greening*, *37*(June 2017), 3–12. https://doi.org/10.1016/j.ufug.2018.02.011

European Commission. Directorate-General for Research and Innovation. (2015). Towards an EU research and innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities : final report of the Horizon 2020 expert group on 'Nature-based solutions and re-naturing cities' : (full version).

European Commisison (2016). Nature-based solutions webpage, retrieved from http://publications.europa.eu/resource/cellar/fb117980-d5aa-46df-8edc-af367cddc202.0001.04/DOC_2 Last access 12 November 2020

European Commission. (2019). EU guidance on integrating ecosystems and their services into decision-making EN.

fisher, brendan, & Grima, N. (2020). *The importance of urban natural areas and urban ecosystem services during the COVID-19 pandemic*. https://doi.org/10.31235/osf.io/sd3h6

Fisher, B., Turner, R. K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643–653. https://doi.org/10.1016/J.ECOLECON.2008.09.014

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio*, *31*(5), 437–440. https://doi.org/10.1579/0044-7447-31.5.437

Forrest, R., & Kearns, A. (2001). Social Cohesion, Social Capital and the Neighbourhood. *Urban Studies*, *38*(12), 2125–2143.

Frank, B. (2017). Urban Systems: A Socio-Ecological System Perspective. *Sociology International Journal*, *1*(1). https://doi.org/10.15406/sij.2017.01.00001

Frantzeskaki, N., & Tilie, N. (2014). The dynamics of Urban Ecosystem Governance in Rotterdam, the Netherlands. *Ambio*, *43*, 542–555.

Geneletti, D., & Zardo, L. (2016). Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy*, *50*, 38–47. https://doi.org/10.1016/J.LANDUSEPOL.2015.09.003

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019

Gómez-Baggethun, E., B. MartínLópez, D. Barton, L. Braat, H. Saarikoski, Kelemen, M. García-Llorente, E., J. van den Bergh, P. Arias, P. Berry, L., M. Potschin, H. Keene, R. Dunford, C. Schröter-Schlaack, P. Har 2014 EU FP7 OpenNESS Project Deliverable 4.1.

Grimm, N. B., Faeth, stanley H., Golubiewski, N. E., Redman, C. L., Wu, Jianguo, Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities.pdf. *Science*, *319*, 756760.

Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., … Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, *43*(4), 413–433. https://doi.org/10.1007/s13280-014-0504-0

Haines-Young, R., & Potschin, M. (2016). *The links between biodiversity , ecosystem services and ro y h a ine s - y o un g and mar ion pot s ch in*.

Hansen, R., Pauleit, S. (2014). From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas. *Ambio, 43*:516-529 DOI 10.1007/s13280-014-0510-2

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science and Medicine*, *63*(11), 2847–2863. https://doi.org/10.1016/j.socscimed.2006.07.030

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4:1-23

Holling, C. S. 1996. Engineering resilience versus ecological resilience. Pages 31-44 in P. C. Schulze, editor. Engineering within ecological constraints. National Academy Press, Washington, D.C., USA

Howard, E. (1902). The gardn cities of To-morrow. retrieved from: http://urbanplanning.library.cornell.edu/DOCS/howard.htm

Ibes, D. C. (2015). A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. *Landscape and Urban Planning*, *137*, 122–137. https://doi.org/10.1016/j.landurbplan.2014.12.014

Ikeme, J. (2003). Equity, environmental justice and sustainability: Incomplete approaches in climate change politics. *Global Environmental Change*, *13*(3), 195–206. https://doi.org/10.1016/S0959-3780(03)00047-5

Jansson, Å. (2013). Reaching for a sustainable, Resilient urban future using the lens of ecosystem services. *Ecological Economics*, *86*, 285–291. https://doi.org/10.1016/j.ecolecon.2012.06.013

Kabisch, N. (2015). Ecosystem service implementation and governance challenges in urban green space planning-The case of Berlin, Germany. *Land Use Policy*, *42*, 557–567. https://doi.org/10.1016/j.landusepol.2014.09.005

Kabisch, N., Strohbach, M., Haase, D., & Kronenberg, J. (2016). Urban green space availability in European cities. *Ecological Indicators*, *70*, 586–596. https://doi.org/10.1016/j.ecolind.2016.02.029

Kaczorowska, A., Kain, J. H., Kronenberg, J., & Haase, D. (2016). Ecosystem services in urban land use planning: Integration challenges in complex urban settings—Case of Stockholm. *Ecosystem Services*, *22*, 204–212. https://doi.org/10.1016/j.ecoser.2015.04.006

Kallis, G., Kostakis, V., Lange, S., Muraca, B., Paulson, S., & Schmelzer, M. (2018). Research on Degrowth. *Annual Review of Environment and Resources*, *43*, 291–316. https://doi.org/10.1146/annurev-environ-102017-025941

Kandziora, M., Burkhard, B., & Müller, F. (2013). Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators: A theoretical matrix exercise. *Ecological Indicators*, *28*, 54–78. https://doi.org/10.1016/j.ecolind.2012.09.006

Kenter, J. O., Raymond, C. M., van Riper, C. J., Azzopardi, E., Brear, M. R., Calcagni, F., … Thankappan, S. (2019). Loving the mess: navigating diversity and conflict in social values for sustainability. *Sustainability Science*, *14*(5), 1439–1461. https://doi.org/10.1007/s11625-019-00726-4

La Notte, A., D'Amato, D., Mäkinen, H., Paracchini, M. L., Liquete, C., Egoh, B., … Crossman,

N. D. (2017). Ecosystem services classification: A systems ecology perspective of the cascade framework. *Ecological Indicators*, *74*, 392–402. https://doi.org/10.1016/j.ecolind.2016.11.030

Langemeyer, J., & Connolly, J. J. T. (2020). Weaving notions of justice into urban ecosystem services research and practice. *Environmental Science & Policy*, *109*, 1–14. https://doi.org/10.1016/J.ENVSCI.2020.03.021

Langemeyer, J., Wedgwood, D., McPhearson, T., Baró, F., Madsen, A. L., & Barton, D. N. (2020). Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona. *Science of the Total Environment*, *707*, 135487. https://doi.org/10.1016/j.scitotenv.2019.135487

Larondelle, N., Haase, D., & Kabisch, N. (2014a). Mapping the diversity of regulating ecosystem services in European cities. *Global Environmental Change*, *26*(1), 119–129. https://doi.org/10.1016/j.gloenvcha.2014.04.008

Larondelle, N., Haase, D., & Kabisch, N. (2014b). Mapping the diversity of regulating ecosystem services in European cities. *Global Environmental Change*, *26*(1), 119–129. https://doi.org/10.1016/j.gloenvcha.2014.04.008

Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning. *Risk Management and Healthcare Policy*. https://doi.org/10.2147/RMHP.S61654

Li, P., Sheng, M., Yang, D., & Tang, L. (2019). Evaluating flood regulation ecosystem services under climate, vegetation and reservoir influences. *Ecological Indicators*, *107*(August), 105642. https://doi.org/10.1016/j.ecolind.2019.105642

Li, X., Zhang, C., Li, W., Ricard, R., Meng, Q., & Zhang, W. (2015). Assessing street-level urban greenery using Google Street View and a modified green view index. *Urban Forestry and Urban Greening*, *14*(3), 675–685. https://doi.org/10.1016/j.ufug.2015.06.006

Locatelli B., 2016. Ecosystem Services and Climate Change. In: Routledge Handbook of Ecosystem Services. M. Potschin, R. Haines-Young, R. Fish and R. K. Turner (eds). Routledge, London and New York, pp. 481-490. ISBN 978-1-138-02508-0 https://www. routledge. com/products/9781138025080

Loudon, J.C., (1829) London plan of Loudon. Retrieved from: https://www.gardenvisit.com/landscape_architecture/london_landscape_architecture/landscape_planning_pos_public_open_space/1929_loudon_breathing_zones

MacKinnon K, Sobrevila C, Hickey V et al (2008) Biodiversity, climate change and adaptation: nature-based solutions from the Word Bank portfolio. World Bank, Washington, DC

Maas, J., Verheij, R. A., De Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health*, *63*(12), 967–973. https://doi.org/10.1136/jech.2008.079038

Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M. L., Barredo, J. I., … Lavalle, C. (2016). An indicator framework for assessing ecosystem services in support of the EU Biodiversity Strategy to 2020. *Ecosystem Services*, *17*, 14–23. https://doi.org/10.1016/J.ECOSER.2015.10.023

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., … Hauck, J. (2013). An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. In *Publications office of the European Union, Luxembourg*. https://doi.org/10.2779/12398

Martnez-Harms, M. J., & Balvanera, P. (2012). Methods for mapping ecosystem service supply: A review. *International Journal of Biodiversity Science, Ecosystem Services and Management*, *8*(1–2), 17–25. https://doi.org/10.1080/21513732.2012.663792

Mascarenhas, A., Ramos, T. B., Haase, D., & Santos, R. (2015). Ecosystem services in spatial planning and strategic environmental assessment-A European and Portuguese profile. *Land Use Policy*, *48*, 158–169. https://doi.org/10.1016/j.landusepol.2015.05.012

Massoni, E. S., Barton, D. N., Rusch, G. M., & Gundersen, V. (2018). Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces. *Ecosystem Services*. https://doi.org/10.1016/j.ecoser.2018.02.013

Mazza, L., Bennett, G., Nocker, L. De, Gantioler, S., Margerison, L. L., Kaphengst, C. T., … Diggelen, R. Van. (2011). *Green Infrastructure Implementation and Efficiency. Final report for the European Commission, DG Environment on Contract ENV.B.2/SER/2010/0059*. 288.

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015a). Resilience of and through urban ecosystem services. *Ecosystem Services*, *12*, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015b). Resilience of and through urban ecosystem services. *Ecosystem Services*, *12*, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012

McPhearson, T., Kremer, P., & Hamstead, Z. A. (2013). Mapping ecosystem services in New York City: Applying a social-ecological approach in urban vacant land. *Ecosystem Services*. https://doi.org/10.1016/j.ecoser.2013.06.005

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., … Qureshi, S. (2016a). Advancing Urban Ecology toward a Science of Cities. *BioScience*, *66*(3), 198–212. https://doi.org/10.1093/biosci/biw002

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., … Qureshi, S. (2016b). Advancing Urban Ecology toward a Science of Cities. *BioScience*, *66*(3), 198–212. https://doi.org/10.1093/biosci/biw002

Meerow, S., & Newell, J. P. (2019). Urban resilience for whom, what, when, where, and why? *Urban Geography*, *40*(3), 309–329. https://doi.org/10.1080/02723638.2016.1206395

Meerow, S., Newell, J. P., Mendizabal, M., Heidrich, O., Feliu, E., García-Blanco, G., … Hayden, M. (2004). Reaching for a sustainable, Resilient urban future using the lens of ecosystem services. *Renewable and Sustainable Energy Reviews*, *86*(2), 410–418. https://doi.org/10.1080/02723638.2016.1206395

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38–49. https://doi.org/10.1016/J.LANDURBPLAN.2015.11.011

Millenium Ecosystem Assessent. (2005). *Ecosystems and Human Well-being: Synthesis.* https://doi.org/10.5822/978-1-61091-484-0_1

Mogollón, B., Villamagna, A. M., Frimpong, E. A., & Angermeier, P. L. (2016). Mapping technological and biophysical capacities of watersheds to regulate floods. *Ecological Indicators*, Vol. 61, pp. 483–499. https://doi.org/10.1016/j.ecolind.2015.09.049

Moreno-Jiménez, A., Cañada-Torrecilla, R., Vidal-Domínguez, M. J., Palacios-García, A., & Martínez-Suárez, P. (2016). Assessing environmental justice through potential exposure to air pollution: A socio-spatial analysis in Madrid and Barcelona, Spain. *Geoforum*, *69*, 117–131. https://doi.org/10.1016/j.geoforum.2015.12.008

Nelson, G. C., Bennett, E., Berhe, A. A., Cassman, K. G., Defries, R., Dietz, T., … Zurek, M. (2005). Drivers of change in ecosystem condition and services. *Ecosystems and Human Well-Being; Scenarios. Millenium Ecosystem Assessment* , *2*, 173–222.

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., … Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of The Total Environment*, Vol. 579, pp. 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Niemelä, J. (1999). Ecology and urban planning. *Biodiversity and Conservation*, *8*, 119–131.

Niemelä, J., & McDonnell, M. J. (2013). The History of Urban Ecology. *Urban Ecology*, 5–13. https://doi.org/10.1093/acprof:oso/9780199563562.003.0002
Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening*, *4*(3–4), 115–123. https://doi.org/10.1016/j.ufug.2006.01.007
Olmsted, F.L., (1870) 'The need of public parks'. From a speech he delivered in Boston in 1870. retrieved from: http://alvaradohistory.com/yahoo_site_admin/assets/docs/publicparkscitybeautification.362182108.pdf
Pauleit, S., Ambrose-Oji, B., Andersson, E., Anton, B., Buijs, A., Haase, D., … Konijnendijk van den Bosch, C. (2019). Advancing urban green infrastructure in Europe: Outcomes and reflections from the GREEN SURGE project. *Urban Forestry and Urban Greening*, *40*(May 2018), 4–16. https://doi.org/10.1016/j.ufug.2018.10.006
Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., & Konijnendijk van den Bosch, C. (2017a). *Nature-Based Solutions and Climate Change – Four Shades of Green*. https://doi.org/10.1007/978-3-319-56091-5_3
Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., & Konijnendijk van den Bosch, C. (2017b). *Nature-Based Solutions and Climate Change – Four Shades of Green*. https://doi.org/10.1007/978-3-319-56091-5_3
Pham, T., Apparicio, P., Seguin, A.-M., Landry, S., & Gagnon, M. (2012). Spatial distribution of vegetation in Montreal_ An uneven distribution or environmental inequity.pdf. *Landscape and Urban Planning*, *107*, 212–224.
Potschin, M. B., & Haines-Young, R. H. (2011). Ecosystem services: Exploring a geographical perspective. *Progress in Physical Geography*, *35*(5), 575–594. https://doi.org/10.1177/0309133311423172
Raymond, C. M., Pam, B., Breil, M., Nita, M. R., Kabisch, N., de Bel, M., … Calfapietra, C. (2017). An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. In *EKLIPSE*.
Romero-Lankao, P., Gnatz, D. M., Wilhelmi, O., & Hayden, M. (2016a). Urban sustainability and resilience: From theory to practice. *Sustainability (Switzerland)*, *8*(12). https://doi.org/10.3390/su8121224
Romero-Lankao, P., Gnatz, D. M., Wilhelmi, O., & Hayden, M. (2016b). Urban sustainability and resilience: From theory to practice. *Sustainability (Switzerland)*. https://doi.org/10.3390/su8121224
Rozas-Vásquez, D., Fürst, C., Geneletti, D., & Almendra, O. (2018). Integration of ecosystem services in strategic environmental assessment across spatial planning scales. *Land Use Policy*, *71*, 303–310. https://doi.org/10.1016/j.landusepol.2017.12.015
Runting, R. K., Bryan, B. A., Dee, L. E., Maseyk, F. J. F., Mandle, L., Hamel, P., … Rhodes, J. R. (2017). Incorporating climate change into ecosystem service assessments and decisions: a review. *Global Change Biology*, *23*(1), 28–41. https://doi.org/10.1111/gcb.13457
Rutt, R. L., & Gulsrud, N. M. (2016). Green justice in the city: A new agenda for urban green space research in Europe. *Urban Forestry & Urban Greening*, *19*, 123–127. https://doi.org/10.1016/J.UFUG.2016.07.004
Sauter, I., Kienast, F., Bolliger, J., Winter, B., & Pazúr, R. (2019). Changes in demand and supply of ecosystem services under scenarios of future land use in Vorarlberg, Austria. *Journal of Mountain Science*, *16*(12), 2793–2809. https://doi.org/10.1007/s11629-018-5124-x
Schewenius, M., McPhearson, T., & Elmqvist, T. (2014). Opportunities for increasing resilience and

sustainability of urban social-ecological systems: Insights from the URBES and the cities and biodiversity outlook projects. *Ambio*. https://doi.org/10.1007/s13280-014-0505-z

Schleyer, C., Görg, C., Hauck, J., & Winkler, K. J. (2015). Opportunities and challenges for mainstreaming the ecosystem services concept in the multi-level policy-making within the EU. *Ecosystem Services*, *16*(2015), 174–181. https://doi.org/10.1016/j.ecoser.2015.10.014

Schröter, M., van der Zanden, E. H., van Oudenhoven, A. P. E., Remme, R. P., Serna-Chavez, H. M., de Groot, R. S., & Opdam, P. (2014). Ecosystem Services as a Contested Concept: A Synthesis of Critique and Counter-Arguments. *Conservation Letters*, *7*(6), 514–523. https://doi.org/10.1111/conl.12091

Sellberg, M.M., Ryan, P., Borgström, S. T., Norström, A. V., & Peterson, G. D. (2018). From resilience thinking to Resilience Planning: Lessons from practice. *Journal of Environmental Management*, *217*, 906–918. https://doi.org/10.1016/J.JENVMAN.2018.04.012

Sellberg, My M, Wilkinson, C., & Peterson, G. D. (2018). *Resilience assessment : a useful approach to navigate urban sustainability*. *20*(1).

Spangenberg, J. H., Von Haaren, C., & Settele, J. (2014). The ecosystem Services Cascade: further developing the metaphor. Integrating societal processes to accomodate social processes and planning, and the case of bioenergy. *Ecological Economics*, *104*, 22–32.

Sugiyama, T., Leslie, E., Giles-Corti, B., & Owen, N. (2008). Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology and Community Health*, *62*(5). https://doi.org/10.1136/jech.2007.064287

Tallis, M., Taylor, G., Sinnett, D., & Freer-Smith, P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*, *103*(2), 129–138. https://doi.org/10.1016/j.landurbplan.2011.07.003

TEEB (2010), The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan: London and Washington.

The Conservation Fund (2004) retrieved from: https://www.conservationfund.org/our-work/cities/ last access 26 December 2020

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, *81*(3), 167–178. https://doi.org/10.1016/J.LANDURBPLAN.2007.02.001

van den Bosch, M., & Ode Sang, Å. (2017). Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews. *Environmental Research*, *158*, 373–384. https://doi.org/10.1016/J.ENVRES.2017.05.040

Van Oudenhoven, A. P. E., Petz, K., Alkemade, R., Hein, L., & De Groot, R. S. (2012). Framework for systematic indicator selection to assess effects of land management on ecosystem services. *Ecological Indicators*, *21*, 110–122. https://doi.org/10.1016/j.ecolind.2012.01.012

Vasiljevic, N., & Gavrilovic, S. (2019). Cultural Ecosystem Services. *Springer Nature Switzerland AG 2019. W. Leal Filho et Al. (Eds.), Life on Land, Encyclopedia of the UN Sustainable Development Goals,* 209–218. https://doi.org/10.1007/978-3-319-95981-8_47

Verma, P., & Raghubanshi, A. S. (2018). Urban sustainability indicators: Challenges and opportunities. *Ecological Indicators*, *93*(February), 282–291. https://doi.org/10.1016/j.ecolind.2018.05.007

Villamagna, A. M., Angermeier, P. L., & Bennett, E. M. (2013). Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. *Ecological Complexity*, *15*, 114–121. https://doi.org/10.1016/j.ecocom.2013.07.004

Wallace, K. J. (2007, October 1). Classification of ecosystem services: Problems and solutions. *Biological Conservation*, Vol. 139, pp. 235–246. https://doi.org/10.1016/j.biocon.2007.07.015

Wang, J., & Banzhaf, E. (2018). Towards a better understanding of Green Infrastructure: A critical review. *Ecological Indicators*, *85*, 758–772. https://doi.org/10.1016/J.ECOLIND.2017.09.018

Wen, C., Albert, C., & Von Haaren, C. (2020). Equality in access to urban green spaces: A case study in Hannover, Germany, with a focus on the elderly population. *Urban Forestry and Urban Greening*, *55*(July), 126820. https://doi.org/10.1016/j.ufug.2020.126820

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities 'just green enough.' *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/J.LANDURBPLAN.2014.01.017

Wolff, S., Schulp, C. J. E., & Verburg, P. H. (2015). Mapping ecosystem services demand: A review of current research and future perspectives. *Ecological Indicators*, *55*, 159–171. https://doi.org/10.1016/j.ecolind.2015.03.016

Woodruff, S. C., & BenDor, T. K. (2016). Ecosystem services in urban planning: Comparative paradigms and guidelines for high quality plans. *Landscape and Urban Planning*, *152*, 90–100. https://doi.org/10.1016/j.landurbplan.2016.04.003

Wright Wendel, H. E., Zarger, R. K., & Mihelcic, J. R. (2012). Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. *Landscape and Urban Planning*, *107*(3), 272–282. https://doi.org/10.1016/J.LANDURBPLAN.2012.06.003

5 REGULATING ECOSYSTEM SERVICES TO SUPPORT PLANNING TOWARDS URBAN SUSTAINABILITY AND RESILIENCE

ABSTRACT

Building on the conceptual framework presented in Chapter 4, this chapter aims at contributing to this discussion by presenting its application on the case of the City of Bologna to first assess and map supply and demand of ESs, and then identify areas of priority of intervention. Starting from the existing models, the work develops a tailored approach to map and assess three ESs (water retention and runoff, PM10 removal, and carbon sequestration and storage) that are tested in the city of Bologna and tailored according to available open data. All data are processed in a GIS environment to allow for spatial distribution and visualization of ESs. These maps facilitate defining supply and demands and, consequently, the presence and distribution of ESs deficiencies. Building on the mismatches identified, this chapter also proposes four clusters by grouping the city's districts based on predominant land use (built-up, green urban areas) and tree canopy cover. This classification enabled the identification of intervention priority areas and suggestions of relevant nature-based solutions (NBS) to be implemented in the cities and formulate recommendations for planners and decision makers[1].

---

[1] An adapted version of the content of this chapter has been published in Sustainability 2021, 13, 2787. Vignoli, F.; de Luca, C.; Tondelli, S. A Spatial Ecosystem Services Assessment to Support Decision and Policy Making: The Case of the City of Bologna.

5.1 CASE STUDY: RES IN THE CITY OF BOLOGNA

According to the statistical department of the municipality of Bologna, the population of about 390000 distributed over 140.86 km2, has increased with an average annual variation of +0.32% from 2003 to 2018 (Bologna, 2020). Bologna has slowly grown in the last years, due to an increasing immigration, mostly from other Italian regions. The city covers an area of approximately 140 square km and is characterized by a humid subtropical climate (Cfa Koppen classification).

According to the last City development Plan (Comune di Bologna, 2007), the historical city centre is located 54 m a.s.l. with high population density and imperviousness, while the hills (280 m a.s.l.) and woodlands, accounting for most of the urban forest area, are located in the South of the city. The rest of the city present high share of inhabitants in the first periphery bordering the city centre, with diverse distribution, while most of the agricultural land is located on the west side and the most industrialized site at the north east of the city, on the edge of the Po Plain.

The attention over climate and environmental issues has always been high in the city. Bologna was the first Italian city to develop the Climate Adaptation Plan and it has been front-runner in Italy in including environmental indicators and criteria into urban plan. Moreover, Bologna City Council, together with the Ministry of Economic Development of Poland, is the coordinator of the Urban Agenda partnership on Sustainable Land Use and Nature-Based Solutions (NBSs). The Urban Agenda for the EU was launched in May 2016 with the Pact of Amsterdam(Pact of Amsterdam, 2016). The partnership on Sustainable Land Use and NBSs started in June 2017 and it includes different services from the EU Commission, 8 European cities and metropolitan urban areas, 6 National Ministries, and other relevant stakeholders. The partnership agreed that the balance between urban compactness and achieving high standards of quality of life is one of the major challenges for Europe's urban areas (Urban Agenda Partnership, 2017). In this sense, the role of Ecosystem Services (ES) and Nature-Based Solutions (NBSs) integration into planning documents has been part of the discussion in the development and the implementation of the Action Plan. One of the actions aimed at better understanding the degree of ES integration into sustainability policies and it was implemented in the city of Bologna. Within the work, we reviewed 11 documents (De Luca et al., 2021), related with urban planning, climate policies and environmental and greening policies. The Climate Adaptation Plan is the only document that makes explicit reference to the ES framework, while regulating and cultural ES are mentioned, even though not explicitly, in all the analysed documents. However, an overall framework with clear targets and monitoring programme to increase quality of life and improve urban environment is currently missing. This reflects the issue that ES is still fuzzily considered by most planners and practitioners in Italy, that has a strong tradition of "blueprint plans" that still makes innovation difficult to be acknowledged in urban practice. The lack of interdisciplinary collaboration among different sectors, including planning, environmental and health departments, is one of the main obstacles to the innovation of urban planning tools. Indeed, current targets and objectives, mentioned for example in the Climate Adaptation Plan and in the Action Plan for sustainable energy, are not fully integrated into urban planning documents.

An ES-based planning approach could represent a huge opportunity for Bologna and many other compact cities in Europe to bring nature back into cities via a wide range of different solutions – i.e. green roofs, green walls, green shelters, etc., new UGAs, improving quality of existing UGAs - that could be adopted within dense city aeras contributing to climate adaptation and mitigation targets and to improve health and wellbeing of citizens.

5.2 DATA

The initial step in the mapping and assessment of ES in the city of Bologna, both for RES and CES, was to create a base map in ArcMap. A unique reference system was assigned to all the files: the projected coordinate system WGS 1984 UTM Zone 32N. Secondly, most of spatial data for the city of Bologna, i.e. map of the municipality, districts, census tracks, tree census dataset, have been retrieved by the Open access data platform of the City Council (Comune di Bologna, n.d.) and from the regional geodatabase (Regione Emilia-Romagna, 2018). While land use data retrieved from the Urban Atlas (Copernicus Land monitoring services) would also fit the scope of this work, we collected data from the regional platform, since they were more accurate for our case study. Also, for the whole case study analysis we have referred whenever possible to openly available data retrieved from official sources at the most disaggregated available scale (i.e census track, district, city, metropolitan, regional or national level). The results will be presented referring to pre-established local administrative units (e.g. neighbourhoods, districts, census area) in order to make the different ES maps spatially comparable for the different ES. For regulating ES we will refer to urban districts as the reference local administrative unit. The chosen methods to map and assess Regulating Ecosystem services mostly follow a spatial proxy approach (Vihervaara et al., 2018) using land use categories and derived data to assess ES supply and associating ES demand variables and data to pre-define local administrative units. Even though more complex mathematical modelling, such as remote sensing data and direct field observation and measurement, could provide more reliable outcomes in terms of ES quantification, spatial proxy methods have been considered adequate in the scope of this work (Martnez-Harms & Balvanera, 2012). Indeed, the degree of details used to build ES maps, and the selection of methods and indicators applied, are considered appropriate since the purpose of the work is not to advance in terms of modelling and quantification methods, but rather to propose a spatial-based approach to evaluate ES gaps or surpluses within urban areas, thus supporting local planners and decision makers in adopting conscious decisions for improving urban sustainability and resilience.

5.3 METHODS FOR RES MAPPING AND ASSESSMENT

Concerning current RES supply and demand mapping and assessment, while other ecosystem services can be considered equally important in urban areas (i.e microclimate regulation, noise reduction) considering our case study, we limited the research to climate mitigation and adaptation relevant services - climate regulation (GHG emissions), and runoff control - and air filtering, while different RES have been considered in the ES resilience assessment methods in Chapter 7.

Indeed, concerning microclimate regulation, a large number of studies has been published (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006; Zardo, Geneletti, Pérez-Soba, & Van Eupen, 2017) and standardized methods and tools are being used, such as ENVIMET modelling, in public administration. This practice is increasingly integrated in urban planning processes, mostly with the aim of mitigating the heat island effect, and it was also introduced in the last drawing of the Master Plan of the city of Bologna, where the methods developed within this study are applied and tested. For this reason, we will not investigate it further in this context. As for the assessment of noise reduction through urban GBI, experimental studies presented conflicting evidence, some stating that vegetation does not effectively reduce perception of noise (Joynt & Kang, 2010) and others arguing that the buffering effect of vegetation is significant (Azkorra et al., 2015). Nevertheless, the most prominent limitation in this field is the limited number of studies which reiterates the necessity for further research. While generally it can be considered that the sound insulation effect of vegetation in urban environments is small, this could be improved using specific design and construction techniques as, for instance, the combination of green roofs or wall vegetation with roof screens (Van Renterghem, Hornikx, Forssen, & Botteldooren, 2013). It is beyond the scope of this work to contribute to advance knowledge in this field, still taking in mind that noise reduction can be considered as one of the co-benefits provided by NBSs in the city.

5.3.1 WATER RETENTION

The condition of water resources, that are already under severe pressure in several regions of the world, is worsening due to climate change. For this reason, it is expected that droughts, floods, storms and related catastrophes will become even more critical (Forzieri et al., 2016; Milly, Wetherald, Dunne, & Delworth, 2002), while water scarcity and hydrogeological instability are identified to be critical issues also for the city of Bologna (Comune di Bologna, 2015).

The intensified urbanisation degree due to rapid population growth is causing amplified peak flows and increased flood risk in cities worldwide (Kaspersen et al. 2015) and, at the same time, climate changes are expected to result in the rise of the frequency as well as of the intensity of rainfall, which may lead to more widespread and severe natural disasters. This increases the exposure and vulnerability of urban areas to flooding, and , as a consequence, the social and economic damages in case of a catastrophic flood event (Genovese, 2006). Introducing green infrastructure in urban environments is one of the possible solutions to the consequences of the growth of urbanization and one of the most effective tools for urban climate change adaptation (Razzaghmanesh, Beecham, & Salemi, 2016) since it enhances run-off control and water retention supporting water cycle regulation and management. In the context of this work, we will look at water retention as the capacity of the soil to maintain and store water, or infiltration (Chen et al., 2019; Larondelle & Lauf, 2016), while we will look at the demand considering the water consumption requested by the diverse sectors operating within urban boundaries. Indeed, as in other similar case studies (see Chen et al., 2019), we consider that water retention service benefits city residents by sustaining water supplies to satisfy the actual water demand, even though historical events of flooded areas in the city could have been used as spatial proxies of run-off regulation demand.

5.3.1.1 WATER RETENTION SUPPLY

Flood and water management are normally calculated using remote sensing images, hydrological modelling and spatial proxy methods (Vihervaara et al. 2018). The purpose of this work is to assess water retention, for which spatial proxy method based on land use map will be used. While water retention supply strictly depends on land use and land cover, we will then aggregate the value at district level to obtain comparable results among different districts.

The overall supply (S) can be computed as the product of the total precipitation (P) times a coefficient of water infiltration based on current land use (Winf) (Pauleit & Duhme, 2000):

$$S\,[mm] = P\,[mm] \cdot Winf\,[\%], \quad (1)$$

The supply is computed for each land use class and further aggregated over the districts' areas (2).

$$S_{w,district}[mm] = \frac{\Sigma(S_{w,land\ use}[mm] \cdot A_{land\ use}\,[m^2])}{A_{district}[m^2]} \quad (2)$$

5.3.1.2 WATER RETENTION DEMAND

The demand for water (3) is considered as the total amount of water consumed for different purposes within the city (Chen et al. 2019) and whenever possible is distributed within the different districts of the city, as explained below.

$$D\,[mm] = Dres + Dagr + Dair + Dec + Dind,ter, \qquad (3)$$

Specifically:

Dres; Residential demand (4): data on domestic water consumption per inhabitant (Wres), normally available in urban environmental accounting report or open data platform, should be multiplied by population per district (Pop) and distributed over the residential areas of each district.

$$D_{res}\,[mm] = \frac{Pop\,[inhabitants] \cdot W_{res}\left[\frac{m^3}{inhabitants \cdot year}\right] \cdot 10^3}{A_{res}[ha] \cdot 10^4} \quad (4)$$

Dagr; Agricultural demand (5): all the water needed to irrigate cultivated fields. The percentage of the cultivated area in need of irrigation (Acrop · %irrig) is multiplied by the volume of water needed for the specific crop. Subsequently, agricultural demand is distributed over the agricultural areas, according to the different land use class, that normally report also the type of crops and the respective districts (e.g.Corine land Cover).

$$D_{agricultural}\,[mm] = \frac{(A_{crop}\,[ha] \cdot \%_{irrig}) \cdot W_{crop}\left[\frac{m^3}{ha_{irrig} \cdot year}\right] \cdot 10^3}{A_{crop}[ha] \cdot 10^4} \quad (5)$$

Dair; Airport demand (6): airports are crucial economic businesses within several European cities; producing a high revenue for the territory, they also present important environmental impacts. For this reason, recently more and more airports are investing in sustainability. It is then quite common to find the sustainability report of airports, detailing the consumption of the different resources and their plan to reduce it. Within the scope of this research, the airport's total consumption of water will be distributed over its area.

$$D_{airport}\,[mm] = \frac{W_{airport}\left[\frac{m^3}{year}\right]\cdot 10^3}{A_{airport}[ha]\cdot 10^4}, \quad (6)$$

Dec; Ecological demand (7): refers to the amount of water used to maintain the urban green infrastructure. The volume of water used to water public parks and, more in general, herbaceous green areas (Weco) will then be distributed over parks, villas and green areas associated with the road network (Apark).

$$D_{ecological}\,[mm] = \frac{W_{eco}\left[\frac{m^3}{year}\right]\cdot 10^3}{A_{park}[ha]\cdot 10^4}, \quad (7)$$

Industrial and tertiary demand (8): as no data for this indicator were available for the case study considered with the required spatial detail, it is computed as the difference between the volume of water consumed for non-domestic use (Dnon-dom) and the above-mentioned demands.

$$D_{tot,ind\ and\ ter} = D_{non-dom} - D_{tot,agricultural} - D_{tot,airport} - D_{tot,ecological} \quad (8)$$

The overall Dtot demand is subsequently distributed over the districts' areas (9).

$$D_{w,district}[mm] = \frac{\sum\left(D_{w,land\ use}[mm]\cdot A_{land\ use}[m^2]\right)}{A_{district}[m^2]} \quad (9)$$

5.3.2 AIR FILTERING - PM10 REMOVAL

Air pollution has many different sources, mainly coming from energy production, industries, and agricultural emissions. Specifically, PM10 is a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air, characterized by particles with a diameter smaller than 10 microns and is really harmful for humans causing from asthma to lung cancer and increasing predisposition to respiratory and cardiovascular diseases (Malmqvist et al. 2018, WHO, 2013a). Besides, in the light of the raise of the global COVID-19 pandemic numerous research studies are investigating the influence of air pollutants over COVID-19 spread and mortality rates, demonstrating the existence of a connection between PM10 and virus spreading rate (Hendryx & Luo, 2020; Yao et al., 2020). Indeed, air pollution hamper not just human and ecosystem health, but it can also lead to negative effects to the economy, buildings and artworks (EEA, 2017). Main PM10 sources are mineral dust (mainly Al2O3, Fe, Ti, Sr, CaCO3, Mg, Mn and K), emissions derived from power generation (SO4, V, Zn and Ni), vehicle exhausts (organic and elemental carbon, NO3− and trace elements) and marine aerosol (Na, Cl and Mg). They can be produced by anthropogenic activities (as combustion processes for heating or industrial production) or by natural sources (as forest fires, volcanic eruptions or pollen dispersion). At urban scale, according to a study performed in various EU cities by Querol et al. 2004; Rodríguez et al. 2004, the major contribution sources are traffic (including exhaust and abrasion products), which accounts for 35–55% of PM10, and industry, while accounting for 15–25% of PM10.

In addition, both the levels and composition of ambient air PM depend on the climatology, geology and topography of a given region. Even though this can lead to wide variations in PM levels across the European Union (EU) regions, the European Community fixed limit values for ambient concentrations of PM for the whole EU. In urban areas, Green and Blue Infrastructure components such as trees and herbaceous areas can contribute to reduce PM10 in the air thus, improving overall air quality in the city and representing the air filtering and gas regulation ecosystem services.

5.3.2.1 AIR FILTERING - PM10 REMOVAL SUPPLY

While land cover data (Janssen et al., 2008) or mixed land cover and tree distribution (Salata et al., 2017) have been used in previous study, within this work the supply of air filtering -and specifically PM10 reduction- will be calculated applying PM10 removal rates (RRPM10) to urban tree canopy cover (TCC) and grass cover (GC). Indeed, in accordance with Baró et al., 2014; McPhearson, Kremer, & Hamstead, 2013; Nowak, Crane, & Stevens, 2006a, when data about tree distribution and species are available, TCC can provide more accurate results in terms of air filtering and carbon storage supply. Eq. (10) details how air filtering supply (S) has been computed:

$$S\left[\frac{g}{m^2\cdot year}\right] = \frac{A_{TCC}\,[m^2]\cdot RR_{PM10,trees}\left[\frac{g}{m^2\cdot year}\right]}{A_{district}[m^2]} + \frac{A_{GC}\,[m^2]\cdot RR_{PM10,grass}\left[\frac{g}{m^2\cdot year}\right]}{A_{district}[m^2]} \quad (10)$$

Where:

PM10 Removal Rate RRPM10, trees. Since the capacities of trees varies with the meteorological conditions, air pollution levels, the status and the species of the tree, different coefficients to estimate an average PM10 removal rate have been developed by various scholars. Within this work, we will refer to the values estimated by Geneletti et al. 2020 for the assessment of ecosystem services in the city of Trento (2,73 g/m2 per year).

PM10 Removal Rate RRPM10, grass. Grass and herbaceous also contribute to PM10 deposition and filtering, but with lower removal rate. According to different scholars (Escobedo et al., 2008; McPhearson et al., 2016) the average value of grass removal rate would be around 1.1 g/m2, that correspond approximately to the trees removal rate divided by 2.5.

TCC Treen Canopy Cover and Grass Cover (GC). TCC and GC can be obtained through the i-Tree canopy tool (Baró et al., 2014; Nowak et al., 2006a). I-Tree Canopy is a web-app that can estimate TCC and other land use cover categories (in percentage or square meters) through an analysis of aerial photographs conducted by the user. Accordingly, the results' accuracy relies on the precision and attention of the operator. To understand the distribution of TCC and GC within urban areas, we propose here to run the characterization in the different city districts, or even smaller administrative units, to be able to differentiate and compare different units within the same urban system. Within this work, the following cover classes were included in I-tree to use aerial image to better distinguish among built-up, water and wetland, bare soil and Urban Green, specifically:

- Built up and sealed (BU);
- Water and wetland (W);
- Bare soil (BS);
- Grass and shrubs (GS);
- Trees and woodland (TW)

Thereupon, the software randomly locates points inside the provided boundary and the operator chooses to which category they belong between the registered ones. At the end of the iterative process the tool provides the users with the percentage of the different cover classes, including the tree canopy cover (TCC) and the grass cover (GC).

5.3.2.2 AIR FILTERING - PM10 REMOVAL DEMAND

Demand indicators of regulating ES usually refer to existing normative value or environmental quality standards (EQS) (e.g., air pollution levels for air purification), implicitly considering the vulnerability or exposure of society to these pressures (Baró et al., 2015). The first European directive to introduce the current limits of PM10 concentration is the 1999/30/EC. This legislation required that the respect of the new limits had to be achieved before 2005; they were:

− 24-hour limit value for the protection of human health: 50 μg/m3, not to be exceeded more than 35 times a year;

− Annual limit value for the protection of human health: 40 μg/m3.

Nevertheless, the World Health Organization (WHO) guidelines suggested the restraints of 50 μg/m3 for the annual mean and 20 μg/m3 for 24-hour mean (WHO, 2006).

Air quality standards provide a first evaluation concerning the general conformity to the current laws and guidelines, but they do not review the values that distinguish the real context of the city. Therefore, following the approach of Nowak, Crane, and Stevens 2006, we propose to refer to measured PM10 concentration in urban areas. Data of PM10 concentrations in the air are collected through air quality monitoring stations in cities and those data are normally open access through city web portal. However, concentrations cannot be directly compared to the removal of PM10 supplied by the urban GBI, since they are expressed in two different unit of measurements:

− Concentration: μg/m3;

− Removal: g/m2 per year.

Nevertheless, a key parameter for air pollution is the vertical height above ground in which a particular matter gets mixed with air and is gradually dispersed. According to Chen et al. 2019; Larondelle and Lauf 2016; Nowak, Crane, and Stevens 2006 the column height corresponds to 200 m, considering the lower troposphere and bringing to a total demand presence of PM10 of 4800 μg/m2 per hour.

$$D_{PM10,h} = C_{PM10}\left[\frac{\mu g}{m^3}\right] * 200\left[\frac{m}{h}\right] \qquad (11)$$

Where:

CPM10 is the PM10 concentration detected by the monitoring stations and 200m represents the column height. Since the obtained value would be an average value of PM10 distribution in the city, the classification of differences between districts was made through the evaluation of air quality improvement (AQI) percentage, to be comparable with other studies(Baró et al., 2015; Nowak et al., 2006a). The latter was quantified as removed PM10 (which in this analysis coincides with the supply) divided by the sum of present PM10 (which in this analysis coincides with the demand) and removed PM10.

$$\mathrm{AQI}[\%] = \frac{\mathrm{S_{PM10}}\left[\frac{\mathrm{g}}{\mathrm{m^2 \cdot year}}\right]}{\mathrm{D_{PM10}}\left[\frac{\mathrm{g}}{\mathrm{m^2 \cdot year}}\right] + \mathrm{S_{PM10}}\left[\frac{\mathrm{g}}{\mathrm{m^2 \cdot year}}\right]} \cdot 100 \qquad (12)$$

5.3.3 CARBON SEQUESTRATION AND STORAGE

Carbon dioxide (CO_2) has always been present in atmosphere as a trace gas and it has been necessary for the development of life, enabling photosynthesis and being a greenhouse gas (GHG) that trap infrared radiation. Its presence is caused by both natural and anthropic sources. In the first case, it can be added to the atmosphere through decomposition, ocean release, respiration, volcanoes eruptions and forest fires. On the other hand, human activities contribute to its formation through cement production and the burning of fossil fuels like coal, oil and natural gas. However, the excessive increase of GHG due to human activities, brought to dramatic changes in the carbon cycle and in the terrestrial balance, drastically contributing to climate change (IPCC, 2014). Carbon dioxide, although absorbing less heat per molecule than other GHG, is still the most important, since it is present in high concentrations, it can persist in the atmosphere for longer periods of time and can absorb wavelengths of thermal radiations that other elements cannot. As a matter of fact, increases in the atmospheric carbon dioxide are responsible for about two-thirds of the total energy imbalance that is causing Earth's temperature to rise (Lindsey, 2020). Climate change already has observable and measurable effects on the environment: in 2018 temperature has risen of $0{,}99 \pm 0{,}13°C$ compared to the pre-industrial years (1850-1900)(WMO, 2020), causing decrease of Artic Sea Ice, decrease of land ice sheets, increase of sea level, more intense heat waves (IPCC, 2018).

Nowadays, the extent to which mitigating actions should be adopted is highly controversial and solutions should also be found within urban contexts, since cities are responsible for 75% of global CO_2 emissions (UN,2020). This need is acknowledged by the new Green Deal, according to which Europe should boost its transition towards being the world's first climate-neutral continent by 2050 and one of the three sectors of the European Climate Pact will be related with tree-planting, nature regeneration and greening of urban areas(EU Commission, 2019). Carbon sequestration is the ecosystem service related with the direct removal of CO_2 over a period (i.e one year) and it can be obtained through revegetation and afforestation(Baró et al., 2014). While carbon sequestration is an annual value of carbon dioxide directly remove by urban forests, carbon storage represents the total carbon that can be stored in trees trunks, branches, roots and leaves. This is not a periodic rate of decrease of CO_2, it is intended as the overall capacity of trees and different land covers to remove carbon from the atmosphere. Within this dissertation we will limit the assessment to carbon sequestration.

5.3.3.1 CARBON SEQUESTRATION SUPPLY

In assessing carbon sequestration supply, the contribution of urban forests should be considered since there are no references in literature that confirm carbon sequestration by grass or bare soils (McPhearson et al., 2013). The supply of this ES provided by the urban forest can be computed applying carbon removal rates (RRCO2) to tree canopy cover (ATCC). Nowak and Crane 2002 proposed a value of removal carbon rate equal to 0,3 kgC/m2 of tree canopy cover per year.

$$RR_{CO_2}\left[\frac{g}{m^2 \cdot year}\right] = \frac{RR_C\left[\frac{kgC}{m^2 \cdot year}\right] \cdot 10^3}{C} \quad (13)$$

Where:

RR_{CO_2} is the removal rate of CO2;

RR_C is the removal rate of carbon and is 0,3 kgC/m2 of tree cover per year;

C is the conversion factor that allows to calculate the grams of CO2 if it's known how many grams of C are present.

While working in metric units, a coefficient for grams has to be found. The atomic mass of C is 12 g/mole and the atomic mass of O is 16 g/mole. Consequently, the removal rate for CO2 is:

$$RR_{CO_2} = \frac{0{,}3\left[\frac{kgC}{m^2 \cdot year}\right] \cdot 10^3}{0{,}2727} = 1100 \frac{g}{m^2 \cdot year} \quad (14)$$

Lastly, this coefficient was multiplied by the tree canopy cover per district, evaluated through i-Tree Canopy (as explained in Section 4.3.1.2), and then distributed over each district's area.

$$S\left[\frac{g}{m^2 \cdot year}\right] = \frac{RR_{CO_2}\left[\frac{g}{m^2 \cdot year}\right] \cdot A_{TCC,district}[m^2]}{A_{district}[m^2]} \quad (15)$$

5.3.3.2 CARBON SEQUESTRATION DEMAND

While some authors considered carbon sequestration demand emission reduction and offset targets established at city level (Baró et al., 2015), here we refer to the demand as the overall emissions of CO2 produced by the city in one year. As the available data on emissions are most of the time aggregated at regional, metropolitan or city level, it is proposed that the overall CO2 emissions will be distributed homogeneously throughout the city, not distinguishing between different districts.

When data for local administrative units (i.e emissions per district) are available they would be then be used and applied to the relevant units in the maps.

5.3.4 ASSESSING RES SUPPLY AND DEMAND: ESDR

ES mismatches, expresses unsustainable uptake of ES expressed though unsatisfied demand for ES (Baró et al. 2015). Therefore, an ES mismatch can be defined as the differences in quality or quantity occurring between the capacity, flow and demand of ES. To evaluate mismatches between RES supply and demand and to further inform planning and management decisions based on their spatial distribution, the ecosystem supply-demand ratio (ESDR) dimensionless parameter will be used:

$$ESDR = \frac{S-D}{(S_{max}+D_{max})/2} \qquad (16)$$

As detailed in previous section, within this work, we propose to aggregate ES supply and demand at the smallest spatially relevant local administrative units, where data are available. The ESDR will be then calculated referring to that spatial area (i.e district or census areas), enabling:

- to evaluate the ratio between supply and demand within districts/census areas: if ESDR is greater than zero, an ecosystem service surplus is observed, and the demand is matched by the current supply; otherwise, if ESDR is negative the supply can't meet the demand highlighting the shortage in the distribution of such service;
- the comparison of different districts/census areas within the urban system (Baró et al., 2016), through the creation of a scale composed by comparable dimensionless values.

The ESDR values obtained through the calculation described in (16) are indicators of ES mismatches and can be used to cluster the districts in different classes presenting similar ES mismatches or performances. In order to define the priority of intervention contemplating the considered UESs, ESDR classes referring to the three different mapped parameters per district were summed to obtain a representation of their overall condition.

According to the values obtained, we propose to group districts in four different classes to define priority (very high, high, medium, low) and types of interventions (NBS needed to improve current situation) within the urban area. Also, we propose to associate the ESDR classes with the proportion of land use of that districts (Built up and sealed or green urban areas) and relevant Tree Canopy Cover identified with i-Tree, thus relating priority and types of intervention with easy to assess characteristics of land use.

5.4 REGULATING SERVICES - RESULTS

5.4.1 RUN OFF CONTROL

The Local Climate Profile of Bologna (Comune di Bologna, 2015) shows the current situation of the city and the future scenarios for climate. According to the developed models and scenarios, precipitations will decrease during spring and winter, as well as during summer that will have less rainy days, but with much harder intensity. Therefore, water scarcity and hydrogeological instability are identified to be critical issues for the city.

For the purpose of this study, we used infiltration rates per type of land cover based on Pauleit and Duhme 2000, while the total annual value of precipitation [P] was acquired from the metropolitan city web portal of Bologna (Città metropolitana, n.d.) and refers to 2018. The mean value (709,3 mm) was assigned as constant P in all the districts. Annual values of infiltration (water retention supply) are related to land use (Figure 1) and vary from 5 mm in totally sealed areas (as roads and compact residential fabric) to 380,894 mm in pervious areas. Land use data have been retrieved from the regional geoportal (Regione Emilia Romagna, 2018).

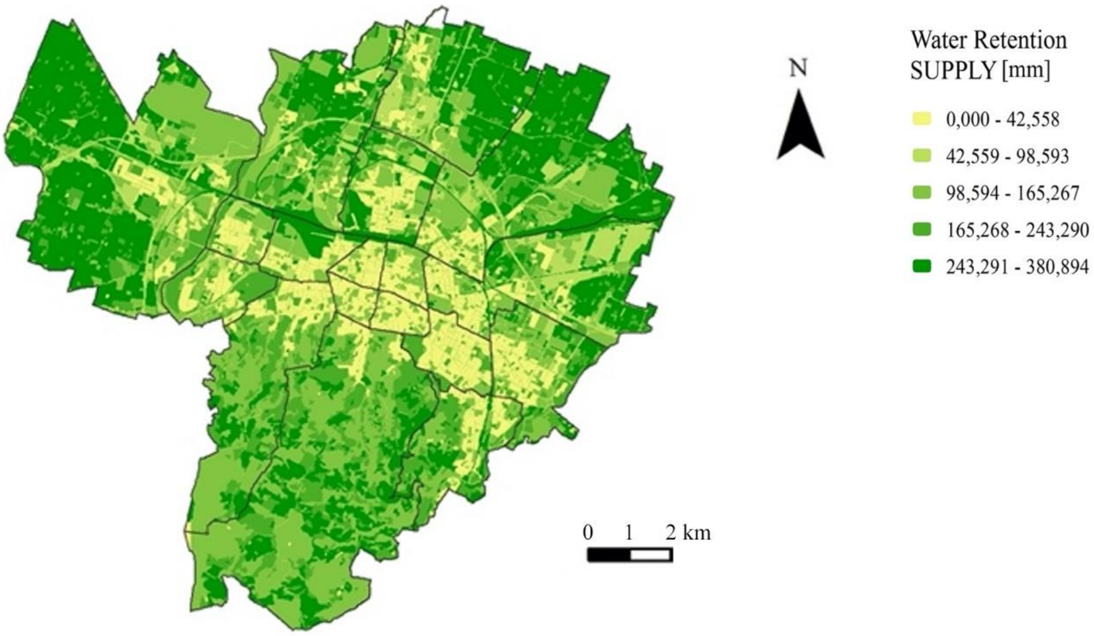


Figure 5-1 Water retention supply according to different land use classes

The obtained supplied for each land use class (Fig. 5-1), was subsequently distributed over the districts' areas to provide results comparable to the other ESs computations (Fig. 5-2).

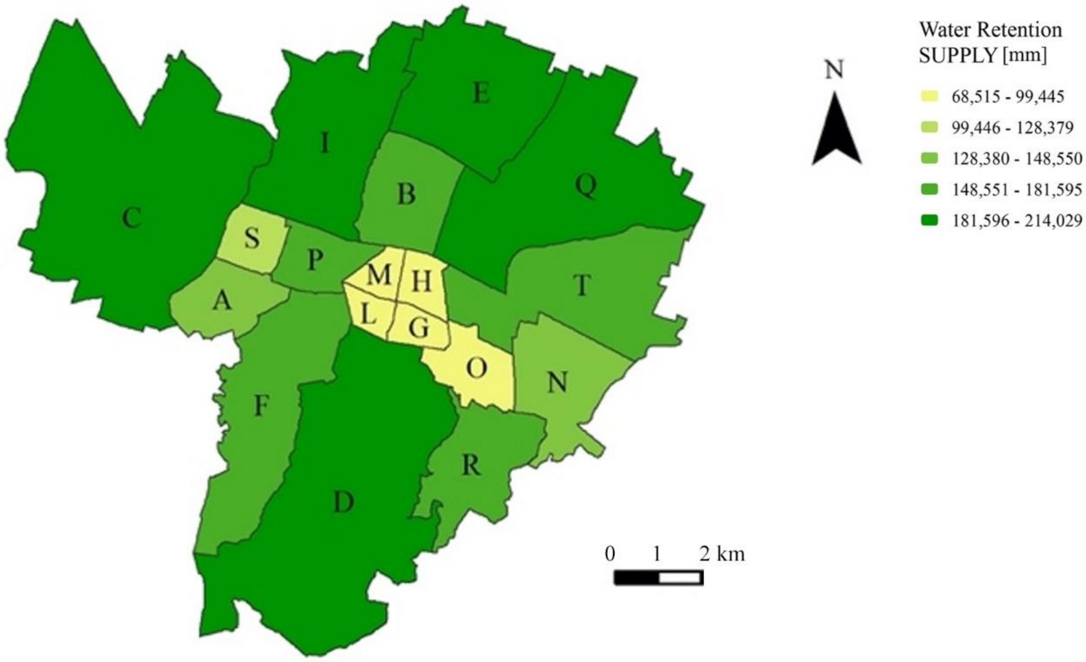


Figure 5-2 Water retention supply aggregated per districts

As clearly showed already in Fig 5-2 and then represented in an aggregated manner in Fig 5-2 the historical districts located at the centre of the urban area of Bologna are reporting the lowest supply in terms of runoff control and water retention, as they represent the most sealed areas of the city. This could lead to flash floods event in the city centre, due to the heavy rains which the city is lately suffering from. In line with Pauleit and Duhme 2000, most peripheral areas, both directing at north, east and south of the city centre, present much higher value of run off control, being those areas mostly covered by either agricultural land or urban forest, thus significantly contributing to groundwater recharge in urban areas.

On the other side, the water retention demand was calculated as the sum of the different water demands per year. Specifically, water for domestic use refers to 2018 and it was retrieved from the open data website of the municipality (Comune di Bologna, n.d. and Città metropolitana, n.d.). While the data for domestic consumption include the overall water consumption of the city (21710 · 103 m^3/year), we divided it per district calculating the consumption of water per capita and the resident population per district. Concerning agricultural demand, we retrieved data from ISTAT 2019 that provides both the irrigation volumes and related areas to be irrigated according to the different crops' type Subsequently, agricultural demand was distributed over the agricultural areas, according to the different land use classes, and the respective districts. The airport contribution to the overall request for water in Bologna comes from the Sustainability Report of the airport (Aeroporto Guglielmo Marconi di Bologna, 2015), that states the overall water consumption to 110,175 m3. As for the ecological request, data come from the Bologna Adaptation Plan (Comune di Bologna, 2015) and are assumed to be stable for 2018. Figure 5-3 and 5-4 respectively represent the water demand per land use and per district. The city centres districts are densely inhabited thus having high water request, mostly for domestic uses. The high presence of industry in north-east districts could justify a higher water request in that area compared to the north west ones, with the southern hilly areas showing the lowest values in the city.

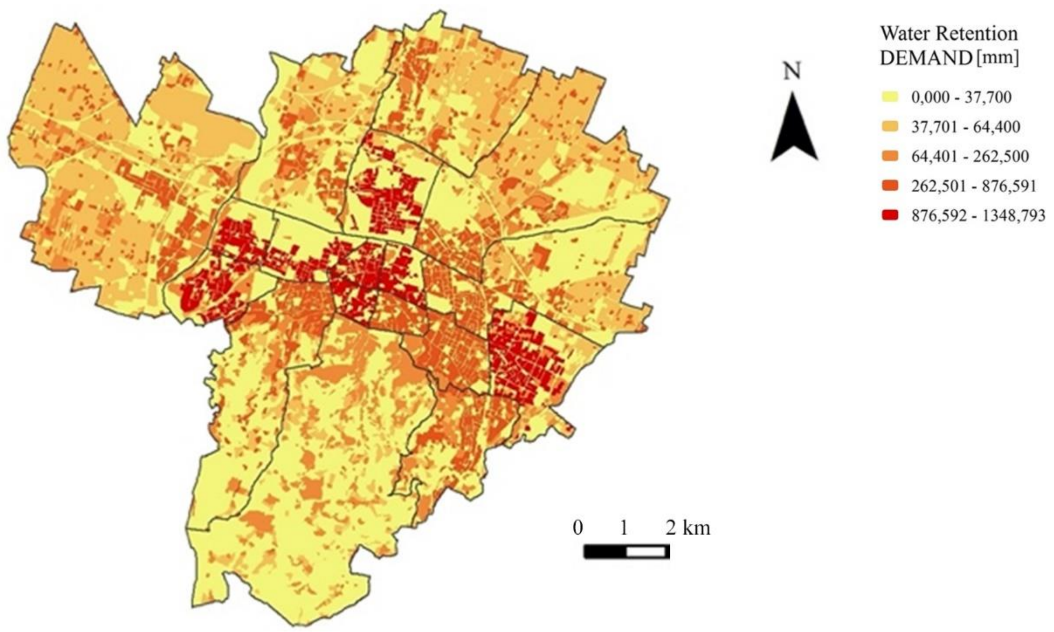


Figure 5-3 Water retention demand according to land use classes

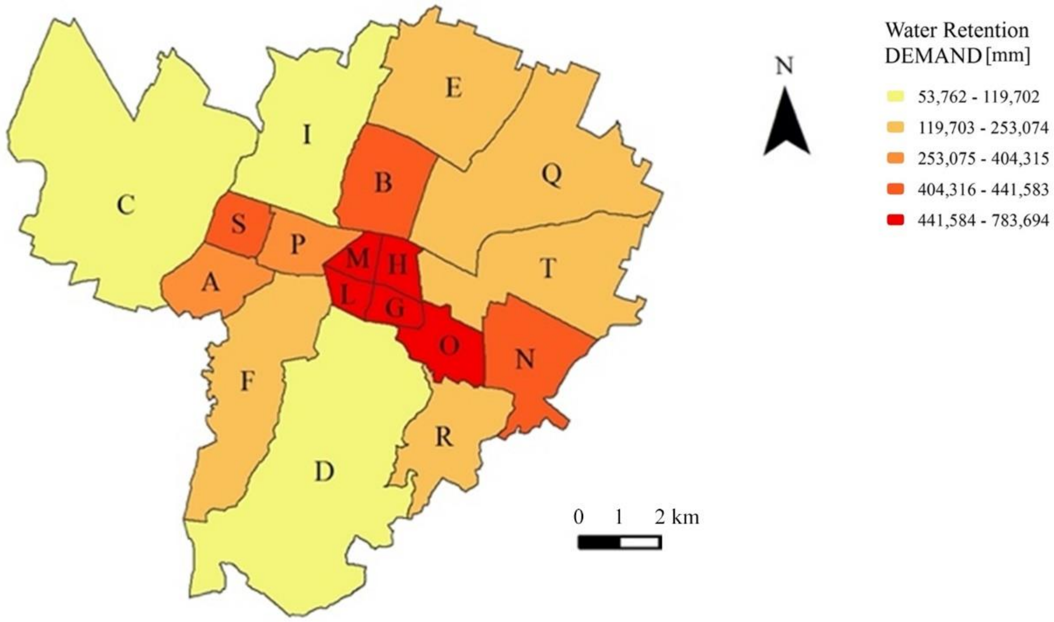


Figure 5-4 Water retention demand aggregated per district

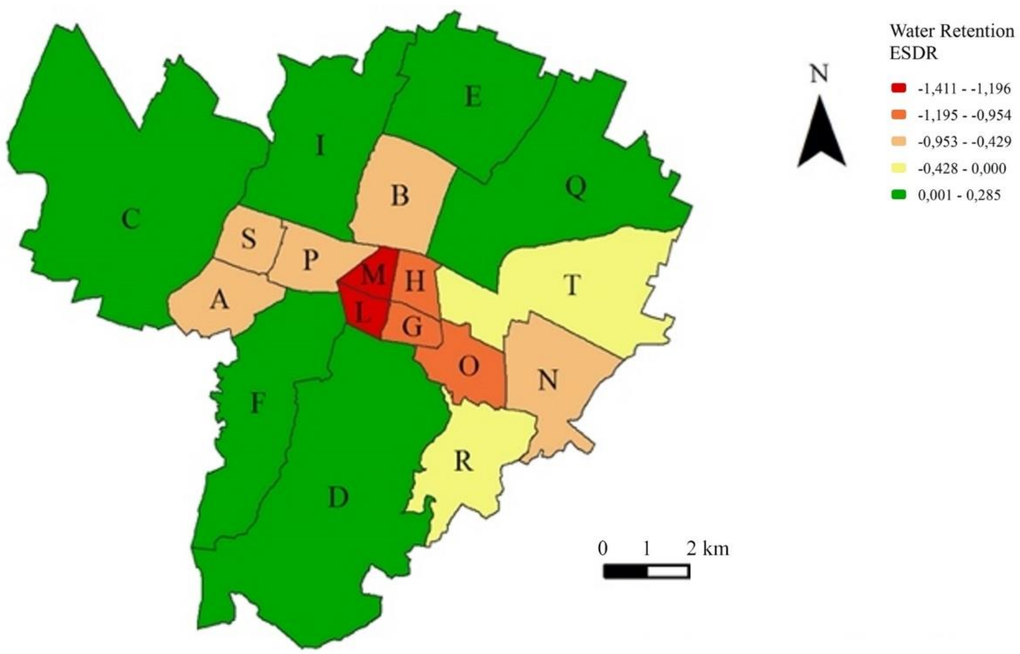


Figure 5-5 Water retention ESDR

Comparing supply and demand through ESDR (Fig. 5-5), it can be observed that shortfalls (ESDR < 0) cease to exist moving from the centre towards the suburban areas. This is clearly related to the highest density of population and imperviousness in the most central neighbourhood. The districts located in the city centre, with the highest rate of residents and thus of densely inhabited and sealed land, are the ones requesting more water, mostly for domestic uses, and at the same time the ones with lower water retention supply, thus presenting the highest supply-demand mismatch of the city. Districts around the city centre mostly heading east and west also presents high ESDR values. These districts are predominately residential areas, thus requesting high amount of water for domestic use and being mostly sealed with residential houses and services. Areas at the north and south of the city present the low or no mismatches, corresponding to the wooded areas of the city (F and D) or containing a high number of pervious areas (i.e agricultural areas, underused land, vacant land)

5.4.2 AIR FILTERING – PM10

During 2019, the annual average concentration of PM10 in Bologna was 26 μg/m3 (Comune di Bologna, 2019), compliant with the annual limit value of 40 μg/m3 imposed by European directive 1999/30/EC (EU Council, 1999). However, this value is not in line with WHO air quality guidelines, that suggest the limit of 20 μg/m3 (WHO, 2006).

Also, in 2019 one of the meteorological stations of Bologna (Porta San Felice) registered 32 days exceeding the 24-hour limit value of 50 μg/m3, close to the limit of 35 days per year (Comune di Bologna, 2019). Even if measures to reduce air pollution have been developed within the Regional Air quality Plan (e.g. implementation of green areas, strengthening of soft mobility, limitations to urban traffic, promotion of electric and hybrid vehicles) the situation is still critic (Regione Emilia-Romagna, 2017). In this assessment, both tree canopy cover and herbaceous cover were considered to calculate particulate matter reduction.

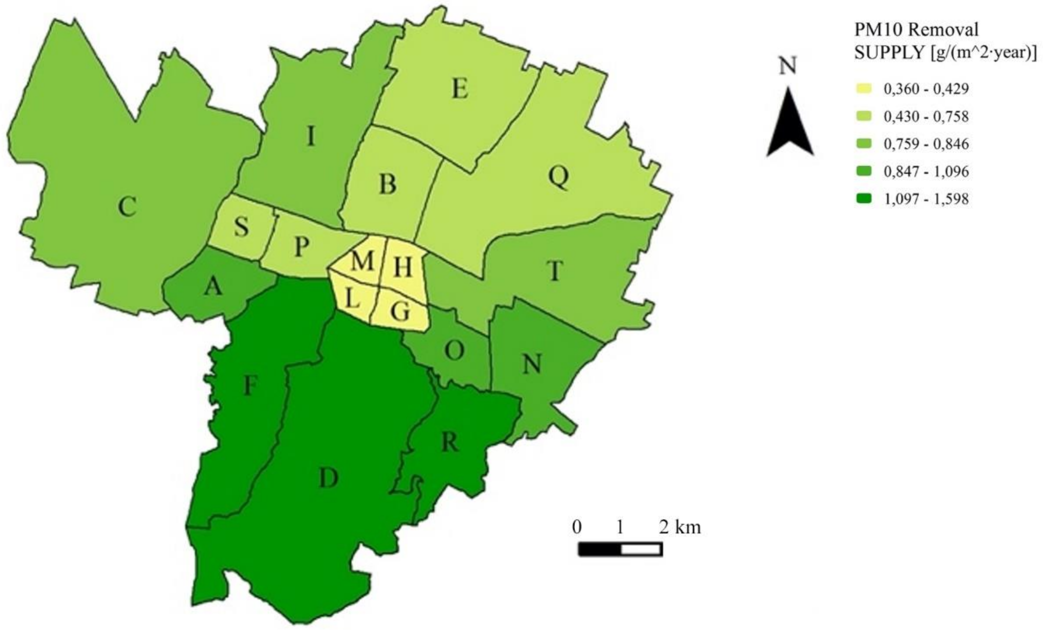


Figure 5-6 PM10 supply provided by the urban GBI in Bologna

To calculate PM10 removal supply services for the city of Bologna we used the removal rate proposed by Geneletti et al. 2020 that sets the trees removal rate of PM10 at 2,73 g/m2 per year and we multiplied it per the tree canopy cover and grass area of each district of the city. The PM 10 removal (Fig. 5-6) supply already provides a clear overview of the distribution of this ES in the city. Indeed, concerning PM10 demand, air quality standards can provide a first evaluation concerning the general conformity to the current laws and guidelines, but in this work, we decided to examine the current concentrations of PM10 in the city. Data about PM10 concentrations are openly accessible through the web portal of the Bologna metropolitan city (Comune di Bologna) and they are collected by ARPAE, the Emilia-Romagna regional agency for prevention, environment and energy. There are three air quality monitoring stations in Bologna that gather data on PM10 concentration. A mean value of 24 μg/m3 was used and then transformed according to the methods described in Section 6.3. We then obtained a spatially uniform demand of 42,048 g/(m2·year). The classification of differences between districts was made through the evaluation of air quality improvement (AQI) percentage (Fig 5-7), to be comparable with other studies (Baró et al., 2015; Nowak, Crane, & Stevens, 2006b). Generally, the percentages of AQI obtained through the this study vary between 0,684% and 2,759%, slightly higher than the ones presented in literature (Baró et al., 2015).

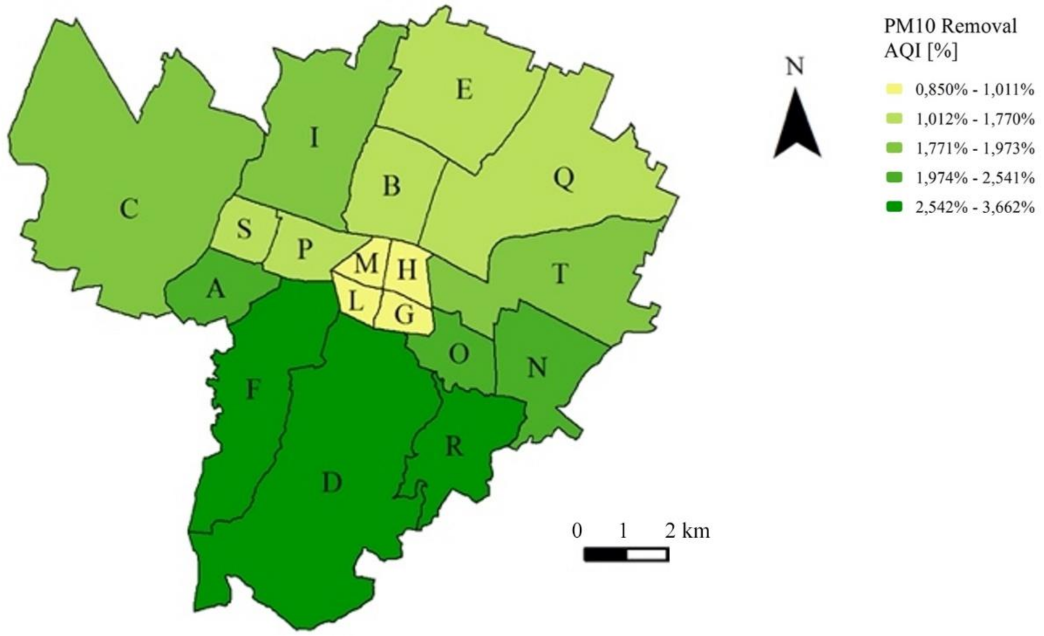


Figure 5-7 Air Quality Improvement (AQI) values per districts supplied by Tree and Grass presented in the area.

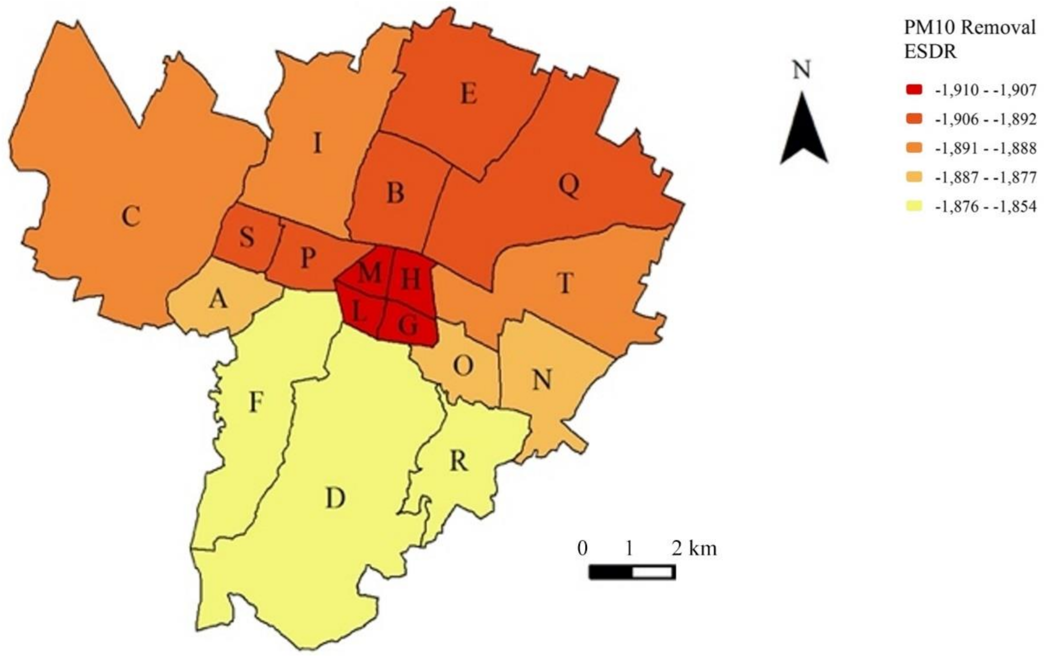


Figure 5-8 PM10 ESDR per district in Bologna

As already described for run-off regulation, Fig. 5-8 shows that districts located in the southern area of the city are the ones that have the major positive impact over the air quality improvement, since they include in their territories a wide quantity of green areas; indeed, most of the urban forest of the cities, completed wood areas with value up to 100% of Tree canopy Coverage (TCC) are in this area. The historical city centre (districts G, H, L, M) shows the lowest supply, and thus the biggest mismatches in terms of ESDR over the whole city. City centre districts present both low values of TCC and of green areas. The northern areas of the city, that performed well in terms of water retention, presents high mismatches in the air quality regulation. Indeed, most of those districts are characterized by agricultural, industrial vacant land, with low percentage of TCC.

5.4.3 GLOBAL CLIMATE REGULATION – CARBON SEQUESTRATION

While PM10 takes in consideration both trees and herbaceous contribution to PM10 removal, just trees contribution to carbon sequestration was evaluated (McPhearson et al., 2013). Fig. 5-9 shows carbon sequestration values in terms of $g/(m^2 \cdot year)$ and presents some interesting differences with the previous PM10 supply assessment. Indeed, wider variation are presented in the different area of the city, depending on the number of trees and related TCC. The historical city centre for instance presents different values among its districts, since district H hosts the biggest and most historical park of the city (Parco della Montagnola), the University Botanical gardens, and many tree lined avenues. On the other side, district C, located at the very west of the city belongs to the worst performing class since it is mostly an agricultural-based district, with limited TCC area.

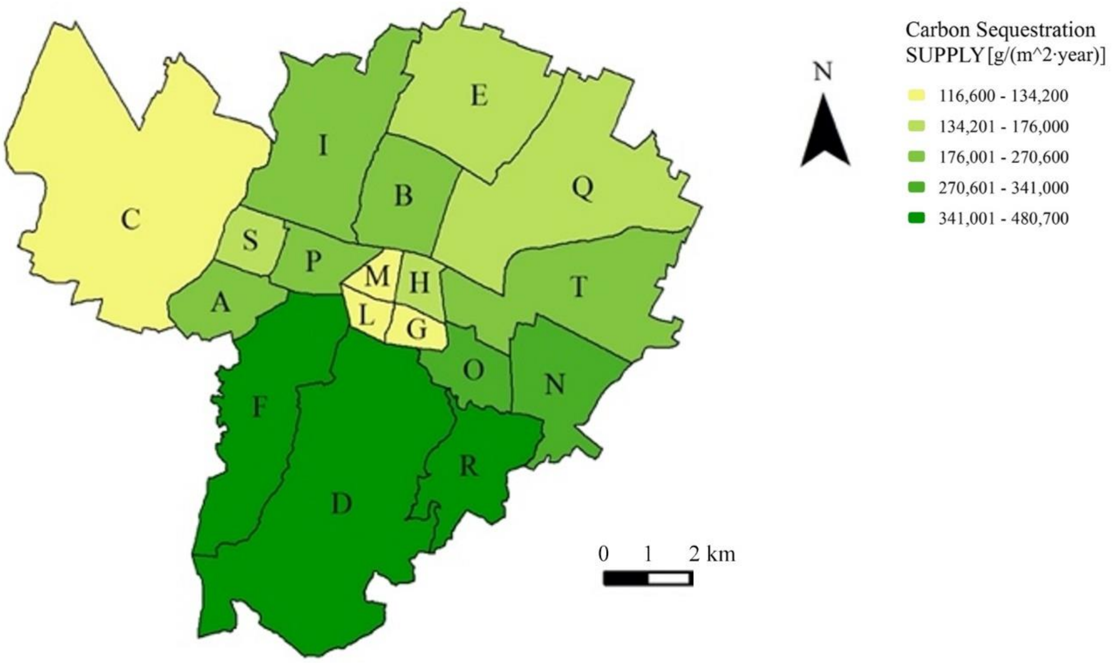


Figure 5-9 Carbon sequestration supply by the urban GBI

As for PM10, it was not possible to evaluate the carbon sequestration demand per district and a unique value was spread over the different city districts. Since data were not available at city level, we used and normalized data regarding CO_2 emissions in the atmosphere coming from the metropolitan level (project INEMAR-ER) produced by ARPAE and Regione Emilia-Romagna (ARPAE, 2020). This value refers to 2017 and corresponds to 1559,816 g/(m^2·year).

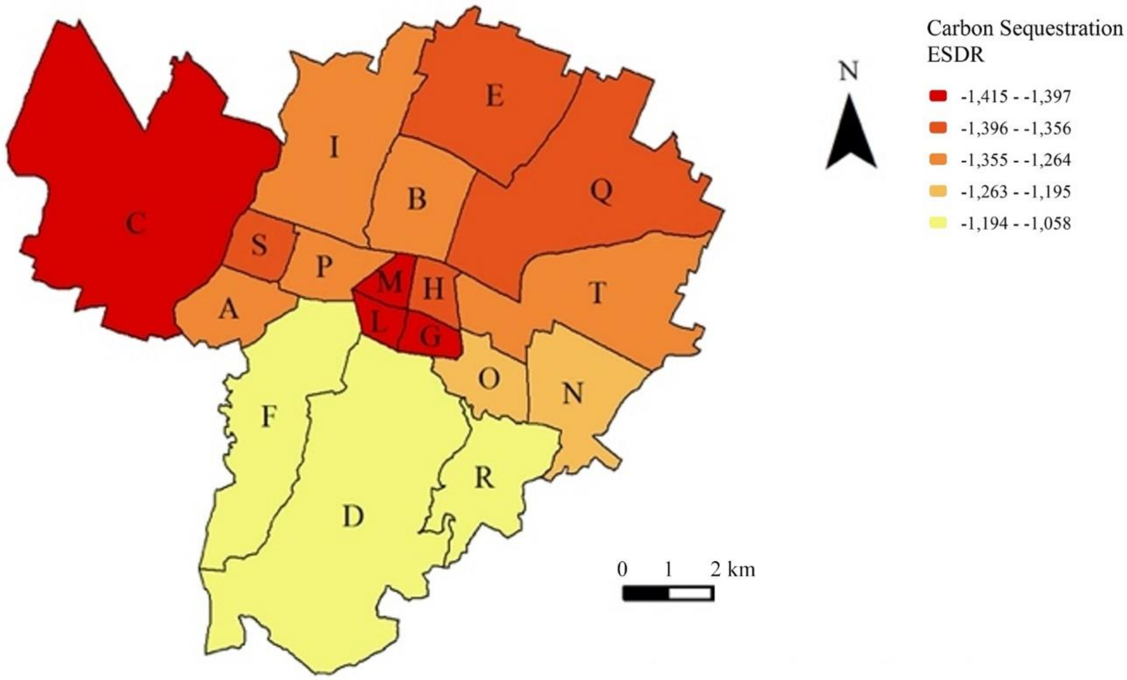


Figure 5-10 Carbon sequestration ESDR

Since the demand is continuously spread throughout the city the ESDR map (Fig. 5-10) reflects the situation presented in the supply map. As already noticed, district H presents a moderately better condition than the average of the city centre districts, due to the presence of one of the biggest urban parks of Bologna (Parco della Montagnola). Also, district C (characterized by the major presence of peri-urban agricultural areas) is characterised by the lowest ESDR class, since it has a multitude of green and agricultural fields but there are hardly any trees. Districts in the hill and woodland city still reveal the highest ESDR, because of their numerous wooded areas.

5.4.4 CLUSTERING DISTRICTS BASED ON THEIR ESDR

For the three ES considered, a value from 1 (lowest ESDR, poorest condition) to 5 (highest ESDR, best condition) was assigned to each district according using an ArcGIS package normalization algorithm. The obtained values, corresponding to the overall performance of each district in relation with the 3 ES considered, have been used to classify the district in four classes (Fig.5-11) characterised by different priority of intervention. District presenting similar ES mismatches also present similar percentage in terms of tree canopy cover and land use classes. This characterization allows to identify 4 classes of districts with similar performance in relation with the 3 ES considered.

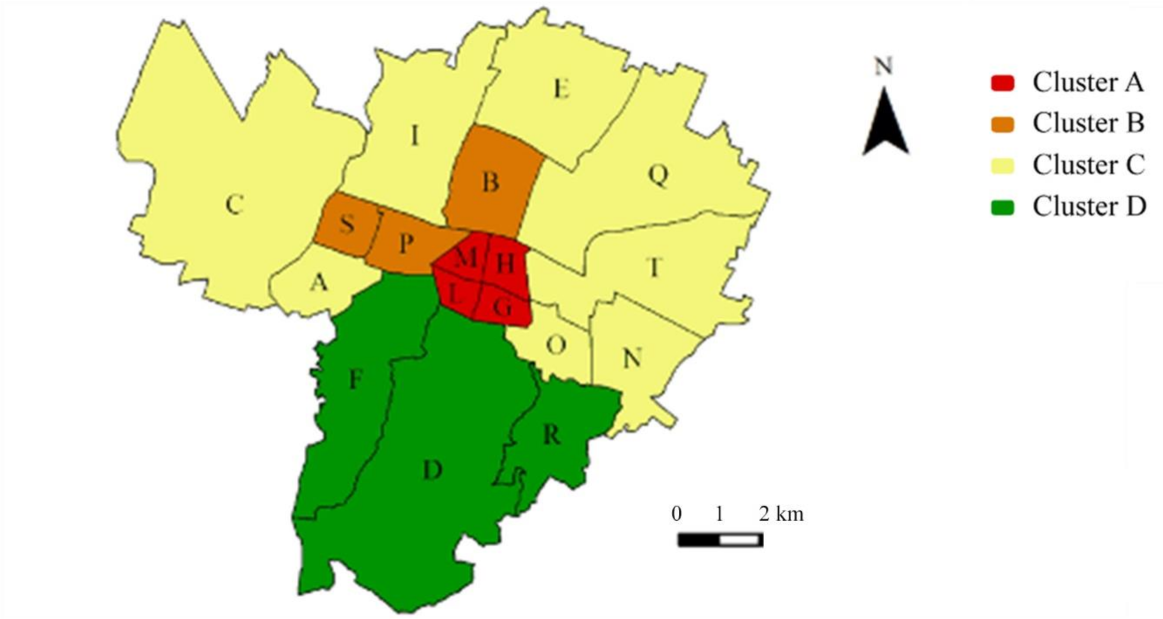


Figure 5-11 Bologna districts cluster according to ES supply-demand mismatches. Mismatches increase from green to red areas.

As Table 5-1 summarizes, ratio of predominant land use (built up and sealed, and green urban areas) and TCC can be considered as proxy of water retention, PM 10 removal and carbon sequestration in urban areas. The first class, Cluster A (see Fig. 5-11 and Tale 5-1) corresponds to districts belonging to the city centre with value of Built Up and Sealed (BUS) land higher than 95% and TCC below 15%. Since these areas present the highest ESDR mismatches for the 3 ES assessed, the priority of intervention has been recognized here as very high. The second class still presents high range of BUS land (not less than 80%) with low percentage of TCC (ranging from 15 to 25%). This cluster still report high mismatches in all the ES, thus the priority of intervention remains high. Cluster C includes the higher variability including districts with very different characteristics, as BUS from 40 to 85% and UGA up to 60%, with still limited value of TCC (up to 35%). This cluster present the widest variation of performances of the 3 ES, thus priority of intervention is considered as medium and should refer to the main mismatches identify in the analysis of the individual ES. Last the fourth group (Cluster D) includes the districts with the lowest or no ESDR mismatches, corresponding the hilly and wooded forest of the city. This cluster does not need any intervention concerning the three ES assessed in this work.

Table 5-1 Cluster of Districts according to predominant land use and Tree Canopy Coverage.

District Cluster	Built up and sealed (%)	Green Urban Areas	Tree Canopy cover	Priority of intervention	Suggested intervention
Cluster A	BU>95%	GUA<5%	TCC<15%	Very high	Hybrid NBS, Green Roofs and Green Walls, Single trees, SUDS
Cluster B	85%<BU<95%	5%<UGA<15%	15%<TCC<25 %	High	Hybrid NBS, Green Roofs and Green Walls, Single trees, SUDS Urban regeneration intervention
Cluster C	40%<BU<85%	15%<UGA<60 %	10%<TCC<35 %	Medium	Urban forest, Urban regeneration interventions
Cluster D	BU<50%	GUA>50%	TCC>35%	Low	No priority intervention needed

5.5 REGULATING ECOSYSTEM SERVICES DISCUSSION AND CONCLUSIONS

By comparing supply and demand spatial values through ESDR, it can be observed that shortfalls tend to drop moving from the historical city centre towards the suburban areas for the three ES considered. Concerning water retention supply, the peripheral districts had clearly higher supply performances than the city centre, and, at the same time, water demand was more clustered in the city centre because of the higher population numbers and density (Chen et al. 2019). This led to high shortfalls and negative supply-demand performances and it could be associated with floods and flash floods taking place within the city centre at an increasingly frequent rate, due to climate change. Considering the high rate of population living in the city centre, such floods can heavily affect the urban system provoking economic, social, and environmental damages.

Looking at PM10 removal, results are in line with similar studies. Nowak, Crane, and Stevens 2006a found that AQI went form 0,2% to 1,0% in different cities of the United States and Baró et al. 2015 observed the range 0,5% - 1,89% in 5 European cities in 2011. Even though the AQI computed for the city of Bologna is slightly higher than the ones found in literature, ranging from 0,6% to 2,7%, we still recognized that air quality improvement by trees and grass has a limited impact on PM10 removal and presents modest effects on achieving compliance to limits and guidelines. Despite this, there is evidence that benefits in human health and wellbeing can be seen with almost any decrease in PM10 concentrations (WHO, 2013).

As for carbon sequestration, our study confirms that the contribution of urban forests to regulate CO_2 emission is substantial in absolute terms (Baró et al. 2017) yet modest when compared to overall city levels of GHG emissions. Nevertheless, urban green spaces can play a significant role as carbon sinks (Nowak, Greenfield, Hoehn, & Lapoint, 2013) and carbon sequestration rates are in some cases comparable to other local mitigation strategies based on energy savings (Escobedo, Kroeger, & Wagner, 2011).

Looking at that spatial differences that were found and that have led to the identification of four clusters, we have drafted the following recommendations:

• Cluster A has a priority level 1 –very high. These urban areas are densely built and inhabited and lack of available space. Therefore, hybrid Nature-Based Solutions (NBS) should be considered for improving the local situation. Specifically, even acknowledging the difficulties in de-sealing historical and compact city centres, permeable paving systems should be promoted and incentivized for parking lots and non-historical squares(Ariza et al., 2019); further soil sealing should be avoided and green roofs and walls with high rate of water retention, where possible, should be implemented and incentivized in public and private buildings (Norton et al., 2015; Razzaghmanesh et al., 2016; Van Renterghem et al., 2013). Also, initiatives to reduce the consumption of water and enhance wastewater reuse should be encouraged and incentives for private greening initiatives can be considered.

• Cluster B has a priority level 2 – high priority. In the city of Bologna these areas correspond to semi-central districts, the ones that border the historical city centre. For districts falling in this cluster the proposed strategy should be more shortfall-oriented rather than global. Despite the high share of built-up areas, these areas' overall condition is not as poor as for the ones in cluster A, thanks to the higher presence of the existing trees. Nevertheless, actions and measures aiming at increasing water retention should be seek, to avoid water run-off and to mitigate the risk of flood and flash floods. Hybrid interventions such as green roofs and walls are highly recommended in this area, that, at least in the case of Bologna, also presents less heritage constrains and could undertake heavier renovation interventions on private and public buildings.

• Cluster C as a priority level 3 – medium priority. In Bologna, these areas correspond to the more peripheral districts, with higher rate of vacant or underused land. Even though their performance are not as poor as Cluster A and B, more drastic and decisive interventions can be put in place, that would contribute to improve the overall performance of the city. On the districts belonging to this cluster relies the biggest opportunity of green urban regeneration projects. Indeed, the presence of vacant land, urban voids, building demolition and replacement projects, etc., raises the possibility to design new multi-functional NBSs (urban parks, watercourses to draw new ecological systems or creating new community gardens and ecological corridors) based on the actual main challenges of the area (i.e water retention, PM10 concentration, urban heat island, no open green public space available). These Nature-based interventions would largely contribute to improve the quality of life and health of the citizens living these districts. Even if not in the main purpose of this study, it must be highlighted that within this cluster there is also a high potential for increasing recreational and cultural services.

• Cluster D priority of intervention is 3 –low–, since they present surpluses of water retention ES and show values of PM10 removal and carbon sequestration that are comparable to the highest found in literature for other cities(McPhearson et al., 2013; Nowak et al., 2006a). This consideration does not exclude further interventions but aims at highlighting that operations in this area could have a lower priority in urban strategies and policy making. We acknowledge that even though further analysis would be needed to provide a wider picture of the current situation of regulatory services within the city, these results can serve as useful information to develop an ES-based planning approach in the city of Bologna.

The presented approach for promoting the integration of ES into urban plans and strategies has some limitations that need to be considered:

(1) Ecological coefficients were taken from studies conducted in other cities, but with similar characteristics to Bologna. Even if this does not significantly affect the final classification, more accurate evaluations could be performed by estimating specific coefficients for the city of Bologna.

(2) The influence area of ecosystems and their related services was limited to the districts' boundary, thus not considering interaction between districts or bordering areas outside the city borders.

(3) The results' accuracy can vary with the operator's precision while interpreting the possible ambiguities of Google aerial images though i-Tree Canopy. Also, the spatial proxy methods used to

compute and map Regulating Ecosystem Services in the city are strictly dependent on available data and dataset, so careful attention should be devoted to the step of data acquisition and elaboration. Nevertheless, even though more complex mathematical modelling, remote sensing data and direct field observation and measurement could provide more reliable outcomes in terms of ES quantification, the adopted spatial proxy methods have been considered adequate, in the scope of this work, since they can contribute to:

i) identify 'hotspot' areas with high mismatches of ES supply and demand;
ii) enhance engagement of stakeholders in the co-development and com-implementation of relevant measures to address mismatches;
iii) support decision-makers in setting priorities by communicating the overall benefits and shortcomings through easy-to-read maps of the city;
iv) classify and cluster urban areas, i.e districts, that present similar results in terms of mismatches for ES supply and demand and further define priority and type of intervention;
v) potentially enhancing citizens' valuation of ecosystem services, providing them with a clear understanding of derived ES benefits and raising awareness among the population on the relevance of the urban GBI.

Through the methodological approach for assessing and mapping the supply and demand of the three studied ecosystem services (water retention, PM10 removal and carbon sequestration), this study manages to identify 4 categories of city districts, based on ES mismatches and linked to different priority of intervention levels contributing to the current discussion on the use of ES in planning (Ahern, Cilliers, & Niemelä, 2014; Geneletti et al., 2020). It is also crucial to take in mind that Nature-based solutions provide a wide range of co-benefits, not treated in this study (noise reduction, recreational services, microclimate regulation), but still relevant in terms of land-use and planning decision making processes (for cultural ecosystem services see Chapter 6). Planting trees in dense sealed and built-up areas, or greening bare soil and abandoned areas should be promoted and wisely planned in terms of species that could increase current canopy cover and could adapt to future climate projections or a better choice of species and crown diameters (Nowak & Crane, 2002). In the case of lack of available and unoccupied areas, the positive contribution of green roofs and green walls should be considered and incentivized. Up to now, decision-making in UGAs management is mostly based on cost and aesthetic considerations but less on ecological or climatic criteria, and in this area rely the biggest innovation of the present work in terms of business opportunities, knowledge transfer and nature-based innovation and climate adaptation and mitigation technologies. The possibility to define priority areas of intervention could support local authorities to justify the request of higher performance indicators in certain areas of the city, and to provide incentives for encouraging the uptake of innovative solutions. For instance, area-tailored performance threshold (i.e the volume of water that should be retained in a specific re-development area) or planning standard can be included within the local building code, largely improving not only the overall ES supply in terms of water retention, but also enhancing business opportunities for high-efficient nature-based or hybrid innovation technologies.

Promoting the introduction of ESs into urban plans and strategies, this approach has some limitations that need to be considered: (1) Ecological coefficients were taken from studies conducted in other cities, but with characteristics similar to Bologna. Even if this does not significantly affect the final classification, more accurate evaluations should be considered for further investigation if specific coefficients are estimated for the city of Bologna; (2) in the accounting of PM10 and carbon sequestration demand, unique and homogenous values have been used for all the districts of the city, since more accurate data were not available for the scope of the study. In this line, further research on more accurate data coming from satellite and/or sensor and further analysis through big data analytics may be explored to obtain more precise results; (3) The accuracy of the results can vary with the operator's precision while interpreting the possible ambiguities of Google aerial images though i-Tree Canopy. In addition, the spatial proxy methods used to compute and map regulating ecosystem services in the city strictly depend on available data and the dataset, so careful attention should be devoted to the step of data acquisition and elaboration.

While the results presented in this study can already provide some useful insights to planners of urban areas similar to the case presented in the thesis, further research should be focused on testing the proposed methodology in different cities, enhancing the integration of ES in urban planning and strategies to achieve better life conditions, health and well-being.

LIST OF REFERENCES

Aeroporto Guglielmo Marconi di Bologna S.p.A. (2015) Bilancio Di Sostenibilità 2014

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, 125, 254–259. https://doi.org/10.1016/j.landurbplan.2014.01.020

Ariza, S. L. J., Martínez, J. A., Muñoz, A. F., Quijano, J. P., Rodríguez, J. P., Camacho, L. A., & Díaz-Granados, M. (2019). A multicriteria planning framework to locate and select sustainable urban drainage systems (SUDS) in consolidated urban areas. *Sustainability* (Switzerland), 11(8). https://doi.org/10.3390/su11082312

ARPAE. (2020). AGGIORNAMENTO DELL'INVENTARIO REGIONALE DELLE EMISSIONI IN ATMOSFERA DELL'EMILIA-ROMAGNA RELATIVO ALL'ANNO 2017.

Azkorra, Z., Pérez, G., Coma, J., Cabeza, L. F., Bures, S., Álvaro, J. E., … Urrestarazu, M. (2015). Evaluation of green walls as a passive acoustic insulation system for buildings. *Applied Acoustics*, 89, 46–56. https://doi.org/10.1016/j.apacoust.2014.09.010

Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D. J., & Terradas, J. (2014). Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. *Ambio* 43 (4):466-79. https://doi.org/10.1007/s13280-014-0507-x

Baró, F., Haase, D., Gómez-Baggethun, E., & Frantzeskaki, N. (2015). Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities. *Ecological Indicators*, 55, 146–158. https://doi.org/10.1016/J.ECOLIND.2015.03.013

Baró, F., Palomo, I., Zulian, G., Vizcaino, P., Haase, D., & Gómez-Baggethun, E. (2016). Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy*, 57, 405–417. https://doi.org/10.1016/J.LANDUSEPOL.2016.06.006

Baró F., Gómez-Baggethun E. (2017) Assessing the Potential of Regulating Ecosystem Services as Nature-Based Solutions in Urban Areas. In: Kabisch N., Korn H., Stadler J., Bonn A. (eds) Nature-Based Solutions to Climate Change Adaptation in Urban Areas. *Theory and Practice of Urban Sustainability Transitions*. Springer, Cham. https://doi.org/10.1007/978-3-319-56091-5_9

Chen, J., Jiang, B., Bai, Y., Xu, X., & Alatalo, J. M. (2019). Quantifying ecosystem services supply and demand shortfalls and mismatches for management optimisation. *Science of The Total Environment*, 650, 1426–1439. https://doi.org/10.1016/J.SCITOTENV.2018.09.126

Comune di Bologna. (2007) Piano Strutturale Comunale -PSC- Relazione ilustrativa

Comune di Bologna. (2015). Piano di Adattamento Città di bologna.

Comune di Bologna. (2019).Di Alcuni Inquinanti Nell'aria Rilevata Dalle Centraline Di Bologna. Valori Medi Annui - Serie Storica | I Numeri Di Bologna Available online: http://inumeridibolognametropolitana.it/dati-statistici/concentrazione-di-alcuni-inquinanti-nellaria-rilevata-dalle-centraline-di-bologna (accessed on 29 October 2020)

Città Metropolitana (n.d.) Climatologia - Temperature e Precipitazioni. Available online: http://inumeridibolognametropolitana.it/dati-statistici/ambiente-e-territorio/climatologia. Last access 23 October 2020.

De Luca, C., Tondelli, S., Martin, J., (2021). Ecosystem Services Integration into Local Policies and Strategies in the City of Bologna: Analysis of the State of the Art and Recommendations for Future Development. DOI:10.1007/978-3-030-54345-7. pp.127-139. In Ecosystem Services and Green Infrastructure Perspectives from Spatial Planning in Italy edited by Arcidiacono, A. e Ronchi S.

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation:

analyzing ecosystem services and disservices. *Environmental Pollution* (Barking, Essex : 1987), 159(8–9), 2078–2087. https://doi.org/10.1016/j.envpol.2011.01.010

Escobedo, F. J., Wagner, J. E., Nowak, D. J., De la Maza, C. L., Rodriguez, M., & Crane, D. E. (2008). Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. *Journal of Environmental Management*. https://doi.org/10.1016/j.jenvman.2006.11.029

EU Commission. (2019). The European Green Deal. https://doi.org/10.1017/CBO9781107415324.004

EU Council. (1999). Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air C directive. Official Journal of the European Commission, (163), 41–60.

Forzieri, G., Feyen, L., Russo, S., Vousdoukas, M., Alfieri, L., Outten, S., … Cid, A. (2016). Multi-hazard assessment in Europe under climate change. *Climatic Change*, 137(1–2), 105–119. https://doi.org/10.1007/s10584-016-1661-x

Frank, B. (2017). Urban Systems: A Socio-Ecological System Perspective. *Sociology International Journal*, 1(1). https://doi.org/10.15406/sij.2017.01.00001

Geneletti, D., Cortinovis, C., Zardo, L., & Adem Esmail, B. (2020). Planning for Ecosystem Services in Cities. In Planning for Ecosystem Services in Cities. https://doi.org/10.1007/978-3-030-20024-4_1

Genovese, E. (2006). A methodological approach to land use-based flood damage assessment in urban areas: Prague case study. European Communities, DG-JRC, Ispra, EUR, 39.

Guerry, A. D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G. C., Griffin, R., … Vira, B. (2015). Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National Academy of Sciences of the United States of America*, 112(24), 7348–7355. https://doi.org/10.1073/pnas.1503751112

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science and Medicine*, 63(11), 2847–2863. https://doi.org/10.1016/j.socscimed.2006.07.030

Hendryx, M., & Luo, J. (2020). Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information . (January).

IPBES. (2016). Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform. S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L.A. Acosta, H. R. Akçakaya, L. Br.

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151 Pp. https://doi.org/10.1016/S0022-0248(00)00575-3

IPCC. (2018). Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to. One Earth. https://doi.org/10.1016/j.oneear.2019.10.025

ISTAT. (2019). Utilizzo E Qualità Della Risorsa Idrica in Italia.

Joynt, jennifer L. R., & Kang, J. (2010). The influence of preconceptions on perceived sound reduction by environmental noise barriers. Science of The Total Environment, 408, 4368–4375.

Larondelle, N., & Lauf, S. (2016). Balancing demand and supply of multiple urban ecosystem services on different spatial scales. *Ecosystem Services,* 22, 18–31. https://doi.org/10.1016/J.ECOSER.2016.09.008

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., … Hauck, J. (2013). An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. In Publications office of the European Union, Luxembourg. https://doi.org/10.2779/12398

Malmqvist, E., Oudin, A., Pascal, M., & Medina, S. (2018). Choices Behind Numbers: a Review of the Major Air Pollution Health Impact Assessments in Europe. Current Environmental Health Reports, 5(1), 34–43. https://doi.org/10.1007/s40572-018-0175-2

Marchi, L., Borga, M., Preciso, E., & Gaume, E. (2010). Characterisation of selected extreme flash floods in Europe and implications for flood risk management. *Journal of Hydrology*, 394(1–2), 118–133. https://doi.org/10.1016/j.jhydrol.2010.07.017

Martnez-Harms, M. J., & Balvanera, P. (2012). Methods for mapping ecosystem service supply: A review. I*nternational Journal of Biodiversity Science, Ecosystem Services and Management*, 8(1–2), 17–25. https://doi.org/10.1080/21513732.2012.663792

Mascarenhas, A., Ramos, T. B., Haase, D., & Santos, R. (2015). Ecosystem services in spatial planning and strategic environmental assessment-A European and Portuguese profile. *Land Use Policy, 48*, 158–169. https://doi.org/10.1016/j.landusepol.2015.05.012

McPhearson, T., Kremer, P., & Hamstead, Z. A. (2013). Mapping ecosystem services in New York City: Applying a social-ecological approach in urban vacant land. Ecosystem Services. https://doi.org/10.1016/j.ecoser.2013.06.005

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., … Qureshi, S. (2016). Advancing Urban Ecology toward a Science of Cities. *BioScience*, 66(3), 198–212. https://doi.org/10.1093/biosci/biw002

Milly, P. C. D., Wetherald, R. T., Dunne, K. a, & Delworth, T. L. (2002). Increasing risk of great floods in a changing climate. Nature, 415(6871), 514–517. https://doi.org/10.1038/415514a

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S. G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, 134. https://doi.org/10.1016/j.landurbplan.2014.10.018

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. Environmental Pollution, 116(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006a). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*, 4(3–4), 115–123. https://doi.org/10.1016/J.UFUG.2006.01.007

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution*. https://doi.org/10.1016/j.envpol.2013.03.019

Pact of Amsterdam. (2016). Pact of Amsterdam - Urban agenda for the EU.

Pauleit, S., & Duhme, F. (2000). Assessing the environmental performance of land cover types for urban planning. *Landscape and Urban Planning,* 52(1), 1–20. https://doi.org/10.1016/S0169-2046(00)00109-2

Querol, X., Alastuey, A., Ruiz, C. R., Artiñano, B., Hansson, H. C., Harrison, R. M., … Schneider, J. (2004). Speciation and origin of PM10 and PM2.5 in selected European cities. *Atmospheric Environment*, 38(38), 6547–6555. https://doi.org/10.1016/j.atmosenv.2004.08.037

Razzaghmanesh, M., Beecham, S., & Salemi, T. (2016). The role of green roofs in mitigating Urban Heat Island effects in the metropolitan area of Adelaide, South Australia. *Urban Forestry and Urban Greening,* 15, 89–102. https://doi.org/10.1016/j.ufug.2015.11.013

Regione Emilia-Romagna. (2017). Misure per Il Miglioramento Della Qualità Dell'aria in Attuazione Del Piano Aria Integrato Regionale (Pair 2020) e Del Nuovo Accordo Di Bacino Padano 2017;

Rodríguez, S., Querol, X., Alastuey, A., Viana, M. M., Alarcón, M., Mantilla, E., & Ruiz, C. R. (2004). Comparative PM10-PM2.5 source contribution study at rural, urban and industrial sites during PM episodes in Eastern Spain. *Science of the Total Environment, 328*(1–3), 95–113. https://doi.org/10.1016/S0048-9697(03)00411-X

Salata, S., Ronchi, S., Arcidiacono, A. (2017). Mapping air filtering in urban areas. A land use regression model for Ecosystem Services assessment in planning, Ecosystem Services, 28, 341-350. https://doi.org/10.1016/j.ecoser.2017.09.009

Skougaard Kaspersen, P., Høegh Ravn, N., Arnbjerg-Nielsen, K., Madsen, H., & Drews, M. (2015). Influence of urban land cover changes and climate change for the exposure of European cities to flooding during high-intensity precipitation. IAHS-AISH Proceedings and Reports, 370, 21–27. https://doi.org/10.5194/piahs-370-21-2015

Urban Agenda Partnership. (2017). Urban Agenda for the EU Orientation paper Sustainable Use of Land and Nature-Based Solutions.

Van Renterghem, T., Hornikx, M., Forssen, J., & Botteldooren, D. (2013). The potential of building envelope greening to achieve quietness. *Building and Environment*, 61, 34–44. https://doi.org/10.1016/j.buildenv.2012.12.001

Vihervaara, P., Mononen, L., Nedkov, S., & Viinikka, A. (2018). Biophysical Mapping and Assessment Methods for Ecosystem Services. (May), 72.

WHO. (2006). World health Organization. Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005. 1–21. https://doi.org/10.1016/0004-6981(88)90109-6

WHO. (2013). Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report. https://doi.org/10.1007/BF00379640

WMO. (2020). WMO statement on the status of the global climate in 2019. In World Meteorological Organization.

Yao, Y., Pan, J., Wang, W., Liu, Z., Kan, H., Qiu, Y., … Wang, W. (2020). Association of particulate matter pollution and case fatality rate of COVID-19 in 49 Chinese cities. *Science of the Total Environment*, 741, 140396. https://doi.org/10.1016/j.scitotenv.2020.140396

Zardo, L., Geneletti, D., Pérez-Soba, M., & Van Eupen, M. (2017). Estimating the cooling capacity of green infrastructures to support urban planning. *Ecosystem Services*, 26, 225–235. https://doi.org/10.1016/j.ecoser.2017.06.016

6 CULTURAL ECOSYSTEM SERVICES TO SUPPOTY PLANNING TOWARDS URBAN SUSTAINABILITY AND RESILIENCE

ABSTRACT

Cultural Ecosystem Services (CES) and related flows of benefits – heavily influencing humans' health and personal wellbeing - are usually included under non-consumptive direct use values. However, despite the increasing recognition of their contribution to citizens' quality of life, their intangible nature makes CES to still suffer from poor quantification and lack of integration in decision making and planning processes. Being recognized as a gateway to environmental and ecosystem services stewardship, the capitalization of the societal relevance of CES would largely help to address real-world problems, improving people wellbeing and quality of life. Cultural services strongly depend not only on the characteristics and features of the urban Green and Blue Infrastructures (GBI), but also on preferences and perceptions of the users that interact with the existing GBI, that contribute to co-produce ES related benefits and values. Nevertheless, CES benefits co-production strongly depends on different socio-cultural characteristics of the users (e.g. income, ethno-racial characteristics, age, and other axes of difference). These diverse needs coupled with the uneven accessibility, quality and distribution of urban greenspaces, could affect the way ES are produced and further exacerbate exiting inequalities and disparities. Based on the methodological framework presented in Chapter 4, this chapter further investigate the case study of the city of Bologna, introducing a spatial approach based on a new and pluralistic notion of GBI quality to assess the related CES co-production paths (including sport features quality and local associations' role as Green Stewards in the assessment of CES supply) and CES distributional dimension of justice in the city.

6.1 CASE STUDY: CES IN THE CITY OF BOLOGNA

As we did for regulating Ecosystem Services (RES), the methodological framework developed in Chapter 4 will be tested and tailored for the city of Bologna. Concerning CES, no previous study addresses this topic for the city, while accessibility to UGAs and the availability of green spaces are now under discussion in the development of the new Urban Master Plan.

As introduced in the previous Chapter, Bologna is a quite compact city in the North of Italy, at the heart of the Emilia Romagna region. Apart from the residential and industrial areas, its territory is composed by agricultural land, the southern hilly area and an extended network of public accessible Urban Green Areas (UGA). Since CES flow of benefits imply the interaction of the beneficiaries with the urban GBI, CES supply assessment will be performed just considering public and accessible Urban Green Areas (UGAs), thus not referring to the whole GBI included in the RES supply. Within this Chapter, UGAs will be intended as the public and accessible share of the total urban GBI. To our knowledge, no previous study assessed the accessibility and distribution of those areas and neither its quality.

6.2 DATA

Departing from the methodological framework presented in Chapter 4, to map and assess CES we make use of various data and databases. Most of the spatial data used such as UGAs, road networks, georeferenced building position, and land use come from the open access platform of the Municipality of Bologna[2]. As for the spatial data, the georeferenced information of the population living per civic number was retrieved from direct communication with city functionaries since this information is not publicly available. Most of the other data (e.g. UGA access point, sport feature presence and type) have been acquired through field visits, and analysis through Google Earth and Google Street View, also due to the COVID-19 restrictions in place during most of the data collection period of this study. Last, all the information about Green Stewards has been retrieved by city databases[3] or organic searches through internet browser and social networks.

[2] http://dati.comune.bologna.it/

[3] http://partecipa.comune.bologna.it/beni-comuni, http://www.comune.bologna.it/laboratoriquartiere/

6.3 CES SUPPLY AND CAPACITY MAPPING AND ASSESSMENT METHODS

For mapping and assessing CES, we assume that the range of different features that composed the GBI do not offer the same types, qualities and quantities of benefits to citizens. Factors such as green areas size, natural and anthropic features of the areas, its design and layout, as well as their accessibility contribute to determine differences in supply (Kabisch, Strohbach, Haase, & Kronenberg, 2016). To advance on current gap regarding CES supply assessment and mapping in urban area, we propose to use 2 two main indicators:

- Urban GBI Proximity analysis: within this work we will refer to "proximity" as the distance calculated through a network analysis from UGAs access point through the available road network (Comber, Brunsdon, & Green, 2008; Martins & Nazaré Pereira, 2018). Proximity can thus be considered as one feature of accessibility, defined as the geographical distribution or supply of UGAs. Accessibility refers to '*the ability to approach something and denotes an intrinsic spatial feature related to the possibility for city dwellers to reach a particular place*'(La Rosa, 2014); since accessibility assessment already includes the consideration of the CES demand side (i.e georeferenced population) it will be considered and described in the supply-demand assessment in Section 6.2.3
- Urban Recreation Potential Indicator (URPI): building on current literature, summarized in Chapter 4, we propose a composite indicator to define the overall quality of the urban GBI. We will specifically consider size (Ekkel & de Vries, 2017; Ibes, 2015), sport feature quality (Hegetschweiler et al., 2017)and Urban Green Stewards (Andersson, Enqvist, & Tengö, 2017; Colding & Barthel, 2013).

6.3.1 URBAN GBI PROXIMITY ANALYSIS

Network analyses have demonstrate to provide reliable and detailed results to understand the access to service within urban areas (La Rosa, 2014; Pham, Apparicio, Seguin, Landry, & Gagnon, 2012).Generally, network approaches have been preferred to simpler Euclidean distances as these overestimate general access and are usually more precise (La Rosa, 2014; Quatrini et al., 2019), even though more complex and in need of additional data, i.e road network.

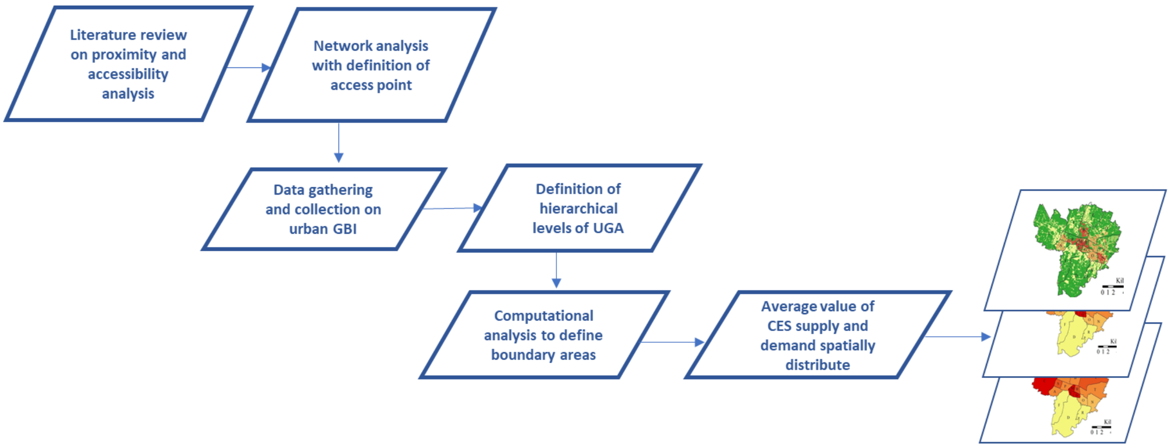


Figure 6-1 Proximity analysis workflow

GIS offers a powerful set of tools for analysing spatial data and provide valuable results for decision making in urban and spatial planning (Comber et al., 2008). In the context of this work we have used ArcGIS, but this analysis can also be replicated using open-source GIS software, such as QGIS, making wider its potential application. As summarized in Fig 6-1, the proposed approach follows a networks analysis as main data entry the following layers:

- UGAs distribution and related size
- Road network (one layer including all road networks that crosses the city, including cycle lane, hiking and pedestrian paths)
- Access points to the UGA as the intersections of the park roads and main road points

In the proximity determination process, network analysis could require mapping access point to UGAs, since they are often not included in the most used database (Corine, Regional Database). If feasible, in terms of city dimension and number of UGAs analysed, the access points can be identified using the ArcMap World Imagery Basemap, or importing maps made upon Google Earth and Google Maps (Comber et al., 2008). To perform the network analysis, it is then crucial to define the hierarchical proximity levels of UGAs in the city. Since people may choose to cover longer distances to reach a certain place, if this provides a particular service or features (La Rosa, 2014), and different UGAs may have diverse significance, we propose to use hierarchical levels by applying different network distances to different UGAs size. According to Grunewald et al., 2017; Gupta, Roy, Luthra, Maithani, & Mahavir, 2016, we will analyse UGAs proximity as walking distances from the identified access point of the UGAs. To identify the diverse values of walking distances we have referred to existing literature (Grunewald et al., 2017, Maes et al. 2016), futher adapting the diverse hierarchical levels to the case study of Bologna. Indeed, the literature analyzed proposed case studies covering mostly metropolis, which hierarchial distances may result inappropriate for the case of a midlle-size city, such as Bologna. The hierarchical classes we propose to use in the network analyses are presented in Table 6.1. Nevertheless, it is worth to underline that such classes could need further re-tailoring based on the dimension, context, density and planning settings of the region of analysis.

Table 6-1 Hierarchical classes of UGAs based on their area (Ha) and walking distance (m)

UGA Class	Area	Distance
POCKET PARK	0 – 0,5 Ha	200m
COMMUNITY PARK	0,5 – 2,5 Ha	300m
NEIGHBORHOOD PARK	2,5 – 10 Ha	500m
URBAN PARK	> 10 Ha	1000-2500-5000m

The network analysis will produce polygons around each UGA that correspond to the area of the city that could potentially be covered by the Cultural Ecosystem Services provided by that area. The 300m proximity values, regardless the UGAs size as suggested by the WHO (WHO, 2016), will be then used to assess possible mismatches around the CES supply (proximity and URPI) and the expected demand in terms of resident population and its vulnerability.

6.3.2 THE URBAN RECREATION POTENTIAL INDEX (URPI)

While there is an overall consensus that health and wellbeing benefits generated by UGAs strictly depends on the quality of such spaces (e.g. Francis et al. 2012; Van Herzele and Wiedemann 2003; Ngom et al. 2016), many authors from different disciplines argue about UGAs qualities definition, possible calculation and relative importance with respect to UGA quantity and distribution in the city (J. Chen, Zhou, & Li, 2020; Hegetschweiler et al., 2017; Jerome, Sinnett, Burgess, Calvert, & Mortlock, 2019; Paracchini et al., 2014). Specifically, as introduced in Chapter 4, we developed the Urban Recreation Potential Index (URPI), that will be made of three indicators: i) UGAs size, ii)sport features and iii) Urban Green Stewards (GS), as further detailed below:

i) UGAs size: as a proxy for people's preference for more diverse and bigger areas. To be integrated into the URPI index, UGA sizes will be normalized (min. max normalization) as explained later in this paragraph.

i) Sport feature presence and quality: While most of current studies considered just the mere presence of sport feature into a defined UGA (Hegetschweiler et al., 2017), we propose a new definition of sport features quality. As sport features can be considered enablers of cultural ecosystem services, i.e physical and recreational activities, that generate diverse and crucial health and wellbeing benefits (Ekkel & de Vries, 2017; Lee, Jordan, & Horsley, 2015; WHO, 2016) we argue that based on the different features that the urban GBI is provided with (e.g. running path; sports fields; hiking trails; children playground; advanced sports equipment, elderly sensitive equipment) these flows of benefits could reach diverse target groups. Indeed, children, young and adults, and older adults do not have the same needs in terms of sport features. For instance, children playground and running path would probably not enable elderly physical activities. We then assume that more numerous are the target groups that those features can address (i.e children, young adults, older adults), higher the quality of sport features present in an area is. Sport features presence can be analysed through direct observation (in field or remotely through Google Maps or Earth) or can rely on existing database contained in sport apps (i.e Calystenic App, Strava). After mapping sport features in each UGA, different values will be assigned to each UGA, according to the target groups addressed by the type of features mapped, as shown in Table 6-2.

Table 6-2 Quality values of Sport features available in UGAs per number of target groups addressed

Target groups address	Quality value assigned to the UGA
No target groups addressed – no sport features	0
One target group addressed	0,4
Two target groups addressed	0,8
Three target groups addressed	1

i) <u>Urban Green Stewards</u>. We consider actors enabling nature-based practices and recreation opportunities in green areas as Urban Green Stewards capable to reinforce and enable CES flows within UGA. To assess the presence of these GS in the city we propose to map community-based initiatives, organizations, or single citizens actions active in UGAs, to understand the type of activities they perform (Maintenance, Social, Cultural, Educational, Environmental, Sports) and the frequency of such activities (weekly, monthly, annually, just once). The number of Green Stewards mapped in each UGAs would be then normalized to be composed with the other two variables of the URPI, as further explained here below.

Despite the so-called Hemeroby index could also influence the use of UGAs defining its degree of naturalness (Arnold, Kleeman, & Christine, 2018), it hasn't been considered in the present study since it was hard to distinguish natural features in the type of analysed urban environment . Nevertheless, we acknowledge that this indicator could be relevant in some similar studies and it could be integrated, together with others, as a component of the proposed URPI. The three components of the URPI (size, Sport features quantity and quality and Green Stewards) present different units of measurement. Therefore, we propose a normalization procedure to perform a comparison among different UGAs. Several normalization techniques exist in, but the choice among them depends on the indicators and the scope of the normalization procedures. In this work we proposed to use a Min-Max, 0-Max normalization, identifying, where relevant, outliers to the value function that would need to be removed at first. While concerning sport features quality the assigned value already falls within the 0-1 range (see Table 6-2), the following equation (17) will be used for normalizing the values of the other indicators:

$$z = \frac{x - min(x)}{[max(x) - min(x)]} \quad (17)$$

further adapting in the three different indicators. While z always represents the normalized value (range from 0-1) of the single features (i.e the UGA), x represents the measure valued (i.e size of the area or number of associations active).

$$RPI = \frac{\text{Z\_size} * \text{Z\_Association} * \text{Z\_Sport}}{3} \quad (18)$$

Using equation (18) the 3 components of the URPI have been considered as equally important, but they could be weighted according to stakeholders' and or experts' judgment. While within this work we do not propose a weighted measure, an Analytical Hierarchical process (AHP) considering couple comparison would be suitable for this scope and easy to use in decision making process. Since all the values of the URPIs refer to the single UGA, we would then need to attribute this to a specific spatial unit, i.e. census track. While in Chapter 5 we have referred to city district as spatial unit, within this Chapter we will consider census track as the reference spatial unit. Even though this does not support direct comparison of the results of RES and CES, we believe that this level of detail would be needed for CES assessment. The results and the recommendation raising from RES assessment aim at supporting a strategic level, that allowed to identify priority areas of intervention in the city and at, for instance, including minimum requirement of performance in specific areas. On the other side, in the assessment of CES we need to use a more detailed scale of analysis since we would like to provide recommendation at governance and project level. Aggregating CES supply and demand at city district, for the case of Bologna, would include the risk of losing information, since many districts present very diverse situation both in terms of CES supply and demand. Nevertheless, since census track are contained within and share borders with the abovementioned city districts, it would be possible in future work, to transform and compare the results. This is so far not in the scope of this work.

To spread the UGAs URPI values in the respective census track (CT), we propose to use a weighted average, as expressed in the formula here below:

$$\text{UGAs quality (URPI) per CT} = \frac{\text{URPI}-\text{UGAn1} * \text{m2UGAn1} + \text{URPI}-\text{UGAn2} * \text{m2UGAn2} + \text{URPI}-\text{UGAnx} * \text{m2UGAnx}}{UGA\ total\ area\ per\ CT\ \ (m2)} \quad (19)$$

6.4 CES DEMAND METHODS

CES demand refers to the socio-demographic and socio-economic characteristics, and relative preferences, needs and values of the population (Plieninger, Dijks, Oteros-Rozas, & Bieling, 2013). These factors determine the match between the supply offered by the urban GBI and the services demanded by the population living in the surroundings. Previous studies mainly explored preferences for green spaces, urban forests and parks or conducted surveys for assessing the recreational use and activities within them but paid little attention to green space physical features or only dealt with them in spatially non-explicit ways (Dickinson & Hobbs, 2017; Hegetschweiler et al., 2017). This thesis will not explore expressed preferences of the population through dedicated surveys and campaigning but would rather check for spatial mismatches between CES supply and demand. In addition, CES supply and demand will not only be assessed in quantitative terms, by counting the number of parks or of people accessing them, but also looking at the different quality of the parks supplying CES and at the vulnerability of the population constituting the demand, including their spatial dimension and assuming that different social groups express diverse needs. Therefore, the demand will be assessed as follows:

- Population number: based on the georeferenced location of the population, considering the overall number of people living within certain administrative units, i.e districts or census track (La Rosa, 2014)
- Vulnerability index: vulnerability of the population, calculated through data characteristics (demographic, social and economic) of social groups living in each census track.

While access to georeferenced data about population living in urban area is relatively easy to retrieve and also standardized at EU level (EU population census data source), disaggregated data at census level for the socio-demographic variables are usually harder to find. Within this work we refer to the vulnerability index as a composite indicator developed by the City of Bologna and available per census track area. This vulnerability index includes, among others, variables included in similar studies, such as age (children and elders), socioeconomic status (income and level of educational attainment) and risk of social exclusion (immigration rate) (Baró et al., 2019; Pham et al., 2012). The vulnerability index that will be used in this thesis is composed as summarized in Table 6-3, and each variable is calculated over the census track area considering the overall number of residents in that area.

Table 6-3 Vulnerability Index variables. Each variable is calculated over the census track area considering the overall number of residents in that area

Demographic variable
Total variation in resident population (%) in a defined timeframe
Rate of natural increase/decrease (%) in a defined timeframe
Resident population > 80 years over the total population (%)
Social variables
Residents > 65 years old living alone
Balance of population between 20 and 64 years old (incoming + outgoing) in a defined timeframe
Balance of population – foreigners- between 20 and 64 years old (incoming + outgoing) in a defined timeframe
Foreign resident minors over the total population (%)
Rate of high-educated (i.e Bachelor) residents among the total population
Minors living with single parent over the total amount of minors (%)
Vacant houses (%)
Economic variable
Residents having an income below the 60% of the median value (%)
Families having a total income below the 60% of the median value (%)
Houses rented (%)

This methodology proposes to use a simple mathematical mean to build each composite indicator (i.e demographic, social and economic vulnerability), while a weighted mean can be used to build the overall vulnerability index, according to decision makers, citizens' or experts' judgement that, in different cities, could attribute more relevance to the demographic, social or economic vulnerability (Comune di Bologna, 2018).

6.5 CES SUPPLY AND DEMAND CORRELATION METHOD

6.5.1 ACCESSIBILITY ANALYSIS

To assess distributional access to UGA in the city, a proximity analysis of UGAs will be performed (see 6.3.1), then correlated with CES demand in terms of population georeferenced data (see 6.4). Specifically, the results of the proximity analysis will be clipped in ArcGIS with the georeferenced population data to assess the total amount of served and non-served population.

To highlight hotspots of mismatches and more vulnerable areas in terms of lacking access to UGAs and thus to CES, population accessibility will be assessed aggregating data at census track level, intersecting the census track borders in the proximity map. Specifically, accounting the percentage of served and non-served Census Track population will allow to identify hotspots, to compare among them the different census tracks and to define an overall value of accessibility to UGA per census track. Also, the use of proximity analysis assessed through UGAs access point and of georeferenced population per house number (and not as a reference centroid point of a census track), should reduce the degree of error in the analysis and increase the reliability of the accessibility map (Van Herzele & Wiedemann, 2003). To better evaluate accessibility at a spatial level and to support planners and decision makers in the identification of hotspots of mismatches, three accessibility classes will defined considering the distance of 300m as suggested by WHO, 2016:

- low accessibility (<50% of CSpopulation has access to UGAs within 300m),
- medium accessibility (50% to 70% of CSpopulation has access to UGAs within 300m)
- high accessibility (>70% of CSpopulation has access to UGAs within 300m)

This value will be then used as a proxy of UGA quantity per census track in the distributional justice analysis together with the UGA quality and population vulnerability values.

6.5.2 DISTRIBUTIONAL JUSTICE

Distributional justice concerns the socially just allocation of resources and in the scope of this work it refers to the just and inclusive allocation, access and further usability of UGAs within the city. Specifically, we will look at the *distribution of access rights to ecosystem services* (Sievers-glotzbach, 2013) in the city, making use of the variables previously defined. Indeed, while accessibility analysis shows mismatches in terms of CES quantitative supply (proximity) and quantitative demand (population), without considering qualitative characteristics of the supply (URPI) or the demand (population vulnerability), distributional justice complements the previous results by looking at the relation among these different components. When measuring the existence of inequities in UGA distribution, some methodological decisions need to be made. A first issue is the scale of analysis. In line with Landry and Chakraborty 2009; Tooke, Klinkenberg, and Coops 2010, and as already explained above, we will use census track aggregation as units of analysis. Moreover, population vulnerability values are aggregated at census track level (Comune di Bologna, 2018), thus supporting the decision of using census track as the reference spatial unit of this analysis. Relevant variables needed for the spatial analysis are presented in Table 6-4.

Table 6-4 Variables used in the distributional justice analysis

Study variable and data	Description Dataset	Final indicator	Variable type
Population Vulnerability – CES demand	Socio, economic and demographic indicators needed (Section 4.4.3)	Composite indicator expressed in normalized values per spatial unit (census track)	Continuous from 0 – 1 Discrete: Low-medium-high
UGA quality RPI – CES supply	UGA Sport features N UGA Green Stewards N UGA Size N Data related with UGAs need to be assigned to spatial unit	Composite indicator expressed in normalized values per spatial unit (census track)	Continuous from 0 – 1 Discrete: Low-medium-high
UGA quantity – Accessibility	UGA proximity analysis results Georeferenced population Data obtained from the analysis need to be assigned to spatial unit	Composite indicator expressed in normalized values per spatial unit (census track)	Continuous from 0 – 1 Discrete: Low-medium-high

We will perform both descriptive and spatial statistical analysis to investigate the relation and the dependencies among population vulnerability, UGA quality (URPI) and UGA quantity (accessibility), using:

- Chi square test: to determine whether there is a statistically significant difference between the expected frequencies and the observed frequencies in the considered variables. Discrete data of classes of the 3 variables will be considered.

- Weighted Spatial regression through ArcGIS: According to Pham et al. 2012, multivariate regression, using ordinary least squares models (OLS) can be used to evaluate the association between UGA quantity, quality and vulnerability. Upon the results of the OLS analysis we will then execute a Geographically Weighed Regression (GWR) to understand the spatial distribution of the dependency among vulnerability, UGA quality (URPI) and UGA quantity (accessibility).

6.6 CES SUPPLY RESULTS

6.6.1 PROXIMITY ANALYSIS

As developed in previous section, we performed a network analysis approach to calculate proximity of UGAs in the city of Bologna. To perform the analysis, we used:

- UGAs map. Basing on the Urban GBI map used to compute regulating ES (Regione Emilia Romagna, 2018), we selected the open public UGAs to be used for this calculation. We excluded private, public but not accessible areas and green furniture from the analysis, since not relevant in terms of Cultural Ecosystem Services flow. UGAs map is presented in Fig 6-2
- UGAs access points were manually digitised using the Google map-Basemap layer underlying the ArCGIS interface and were placed inside the greenspace area
- Hierarchical walking distancing according to the UGA classes per size

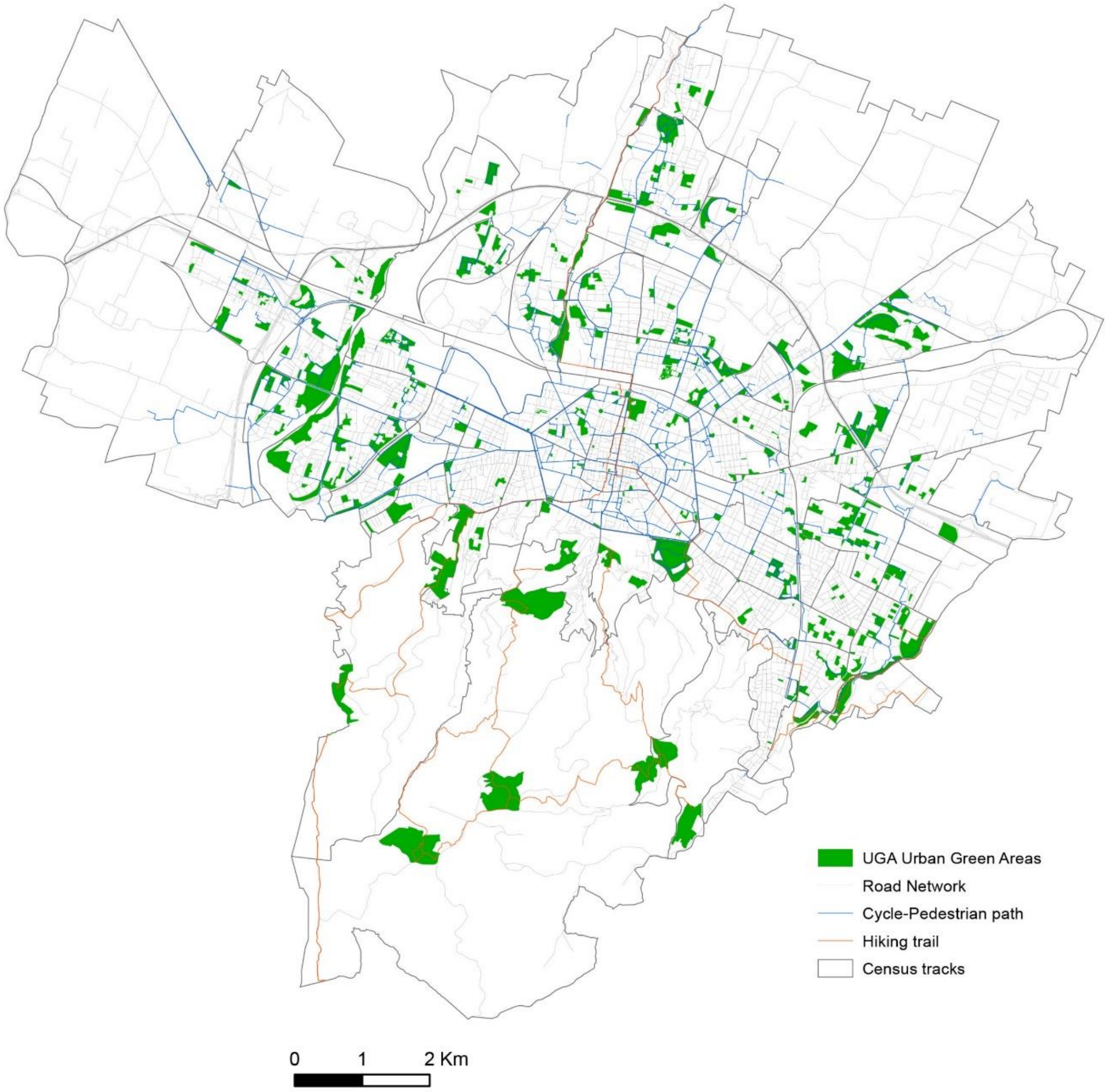


Figure 6-2 UGAs distribution in the city of Bologna

The distribution of UGAs in the city looks inhomogeneous, with small UGAs located within and around the city centre and the first ring of periphery and the biggest UGAs far from the city centre. The southern part of the city, that mostly contributed to regulating service (see results of previous section) present some of the widest UGAs, but they are very isolated and far from the city centre.

Also, most of the wooded areas of that part of the city results to be private, thus not considered in this map.

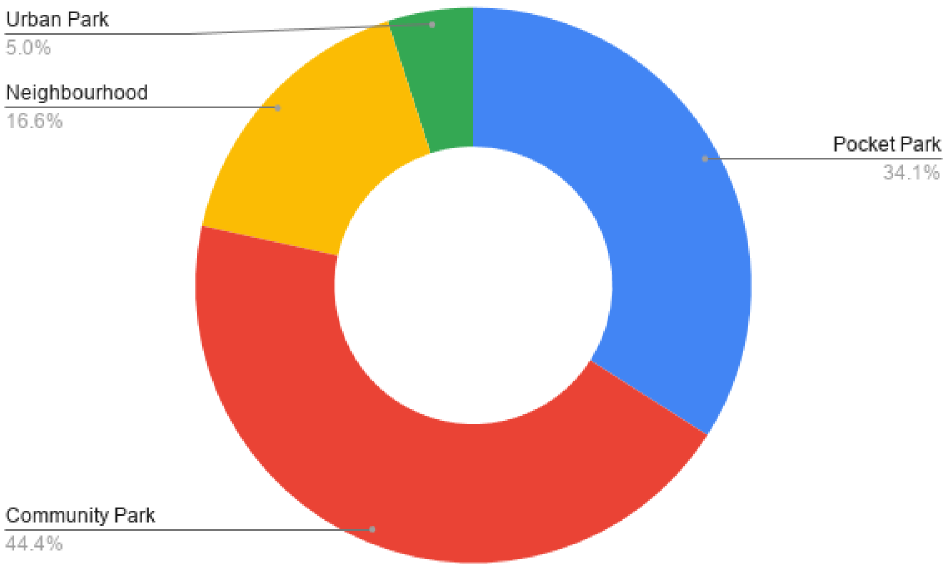


Figure 6-3 UGA type distribution in Bologna

In total, we have identified 321 Urban green Areas in the city, and similar to what has been acknowledged in previous studies (Martins & Nazaré Pereira, 2018), smaller areas are the highest in number. Among those, pocket and community parks (up to 2.5 ha) represent around 80% of the total UGAs of the city, with community parks counting for the majority among all categories (44.4%).

Basing on this observation, we performed 5 different proximity analysis according to the diverse hierarchical level of walking distance and UGAs size. The first network analysis performed considered a walking distance of 300m and took into consideration all UGAs, regardless their sizes, as this is the recommended distance set by the WHO. It is worth to highlight that we will use the results of this first analysis to test following computation for accessibility and distributional justice.

The network analysis for proximity assessment produced polygons that are represented in Fig 6-4 as green buffer areas around UGAs. These buffer areas correspond to the area of the city that could potentially be covered by the Cultural Ecosystem Services provided by UGAs. The buffer areas intersecting the road network within a fixed distance from the access point of the UGAs (300 m) is then covered by the UGAs services. Fig 6.4 shows the results of the proximity analysis of UGA within 300 m walking distance. The map shows that the southern hilly part of the city, despite its high concentration of greenness, include big areas not served by any UGAs, This is partly due to the few access points of the UGAs present in this zone and partly due to the low presence of road network reaching those area. The city centre presents a scattered situation since some areas in the north west are very well covered by the UGA services, and some others, e.g. the southern and eastern areas, present big voids.

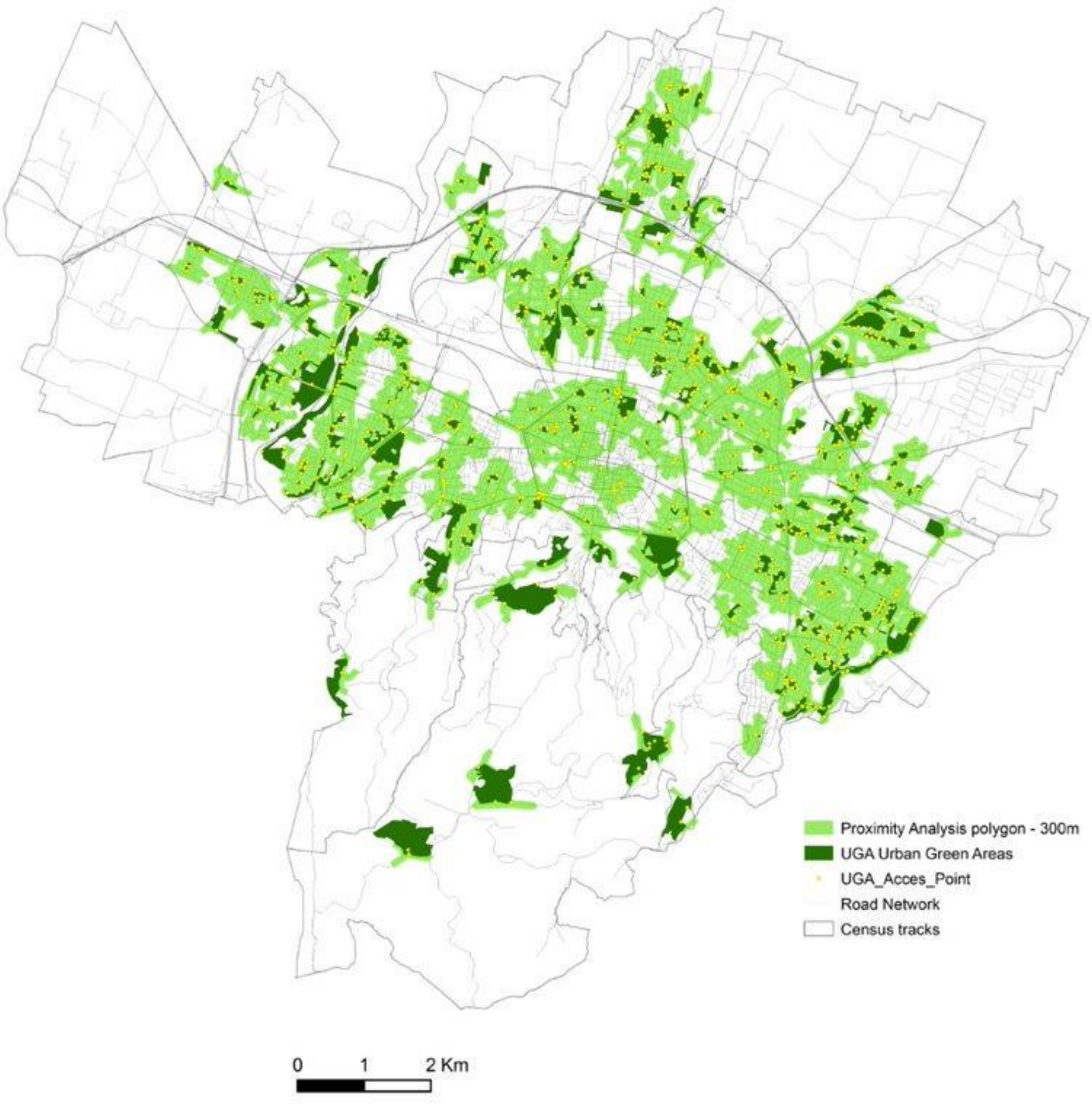
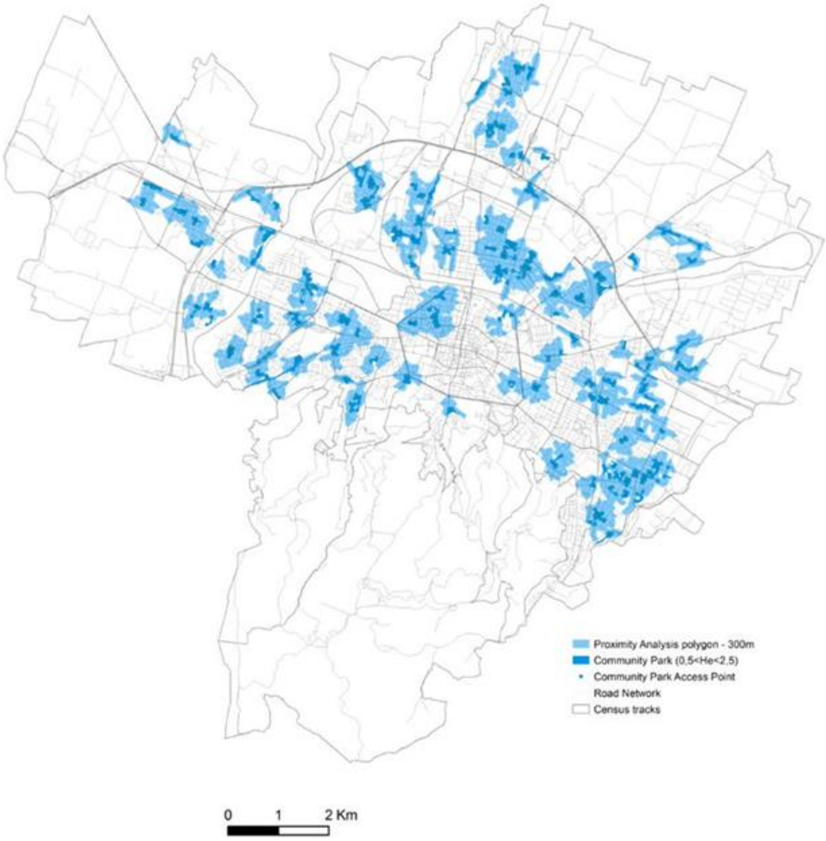


Figure 6-4 Proximity analysis: 300m network distance results

While the proximity analysis already shows some valuable results in terms of areas of the city not served by any UGA, Fig. 6-5 and Fig 6-6 present the results of the proximity analysis using the hierarchical classification of UGAs



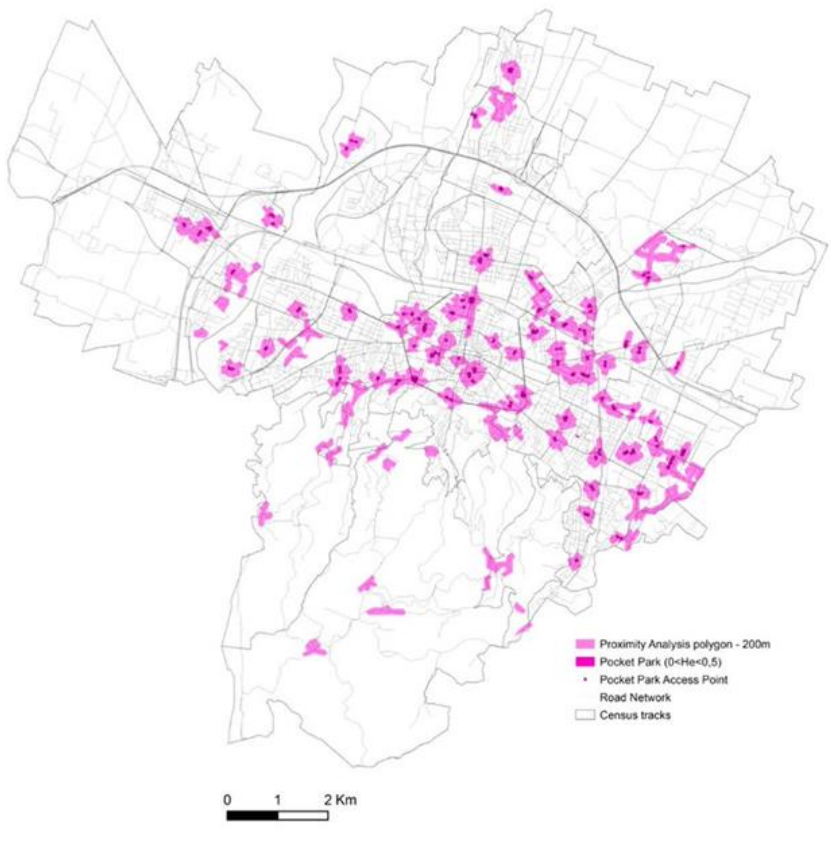


Figure 6-5 Proximity analysis - community (300m) and pocket parks (200m) results

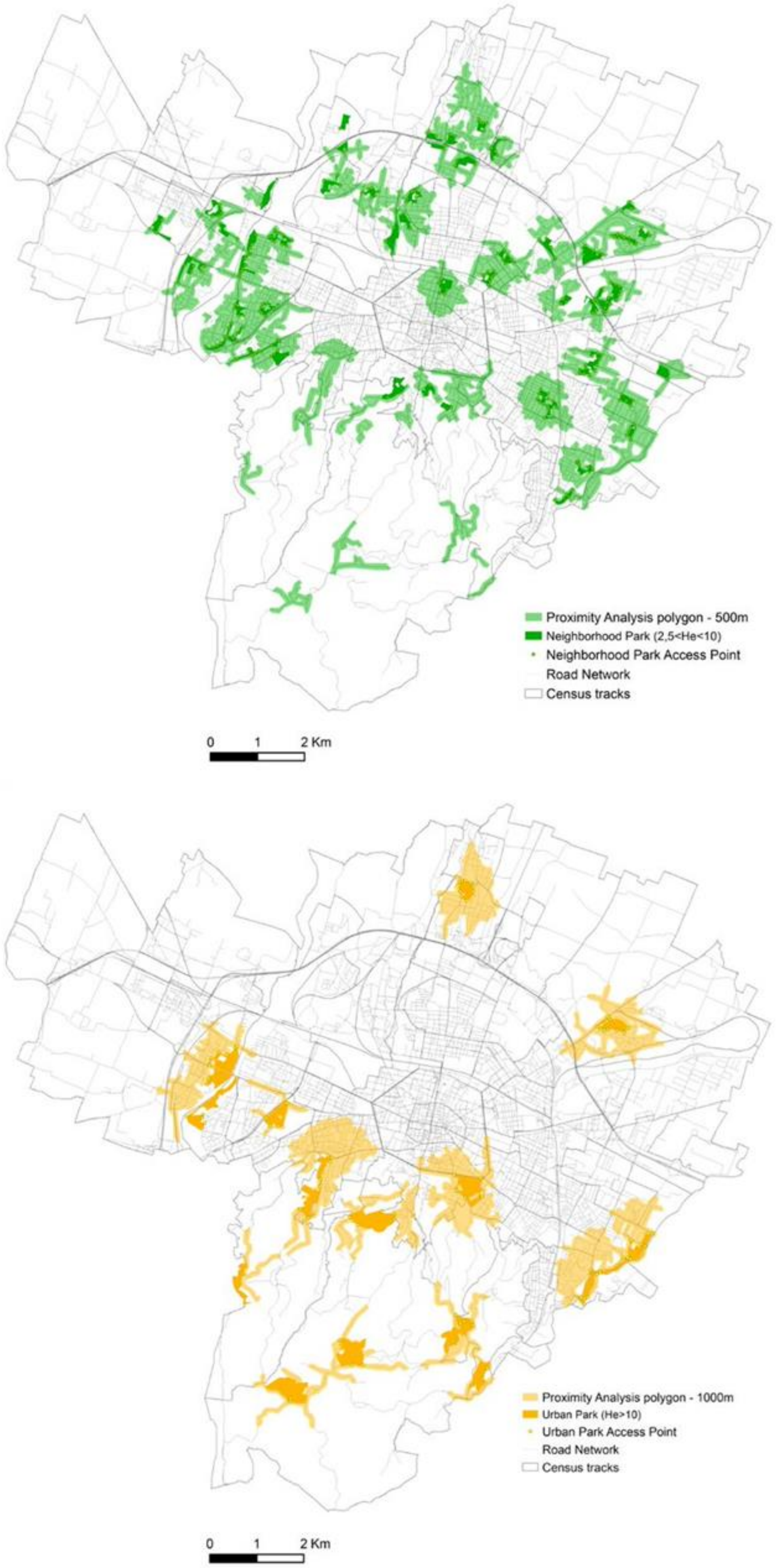


Figure 6-6 Proximity analysis, neighbourhood (500m) and urban park (1000m)

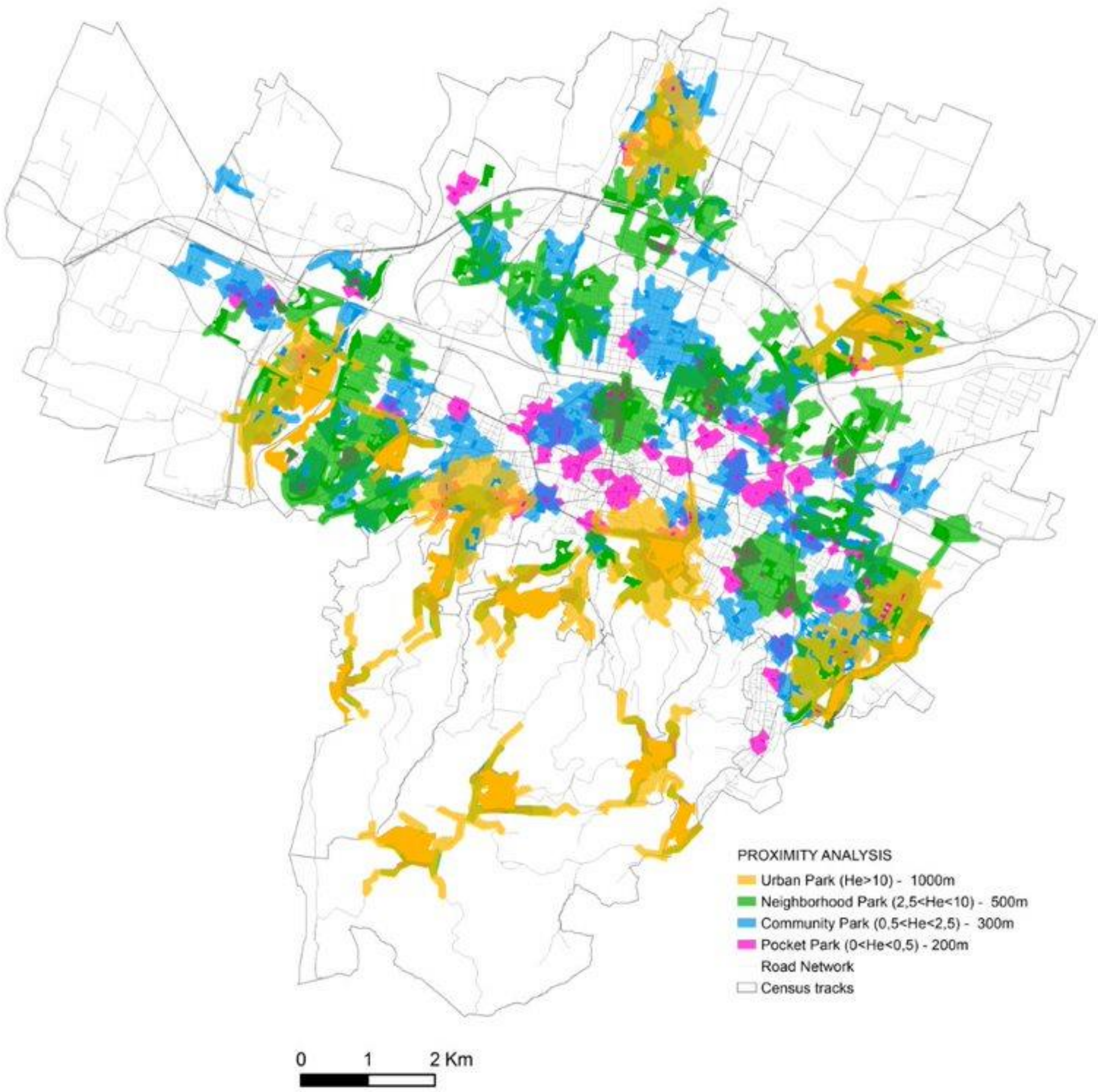


Figure 6-7 Multilevel network analysis considering the 4 hierarchical distances and parks sizes.

Most of city centre districts are covered by pocket and community parks, acknowledging the lack of large recreational green spaces in urban dense city centre and highlighting parts totally deprived by such services, i.e. the south east city centre part. On the other side, while there is just one park that overcome the 2.5 ha threshold in the city centre, Parco della Montagnola in the north-east area of the city, most peripheral districts are covered by bigger UGAs, such as neighbourhoods and urban parks. While urban parks are mostly located in the southern hilly area of the city, except for one urban park covering the north peripheral area, neighbourhood parks are well spread around the city, except for the city centre. Fig 6-7 summarizes the four different analysis overlapping buffer areas of proximity of the 4 hierarchical levels considered in the analysis. The figure summarizes the results already described in terms of part of the city covered by different hierarchical level. Nevertheless, this map provides also additional information. Indeed, the overlapping of different buffer areas highlights not just areas of the city that are served by UGAs, as showed in Fig. 6-4, but it already introduces some additional information over the type, the size and thus the related quality of UGA accessible in the different part of the city. Notably, while the city centre is well covered by the 300m network distance, Fig. 6-7 highlights that most of the services provided by UGAs are coming from pocket and community park, thus relatively small areas (<2.5ha) with consequent limited recreational possibilities. Also, several areas of the city centre are deprived of the access to any kind of UGAs with the hierarchical distances used. On the other side, the southern area of the city centre, that do not have any access to UGA within 300m, results better covered by large urban areas with 1000m network distance. Areas in the first periphery in the northern part of the city are served mostly by community and pocket parks, still leaving wide areas not covered by any UGA. Notably areas at the extreme east and west of the city present many overlapping in the proximity buffer areas, suggesting that those areas are well-covered by the four hierarchical level considered.

6.6.2 UGA QUALITY: URBAN RECREATION POTENTIAL INDEX

As described in Section 6.3.2, the URPI has been built considering 3 different indicators: UGA relative size, UGA sport feature quality and UGA Green Stewards. This section presents first the results of the three diverse indicators and then shows the final composite index for each UGA of the city

6.6.2.1 URBAN GREEN AREAS DIMENSION

The scatter chart (Fig 6-8) shows the size (ha) of all the UGAs mapped in the city of Bologna. As already mentioned in the proximity results, size analysis highlighted that around 80% of UGAs in Bologna are smaller than 2.5 ha and just 5% of the UGA covered an area bigger than 10 ha. The mean value is 2.3 ha, while the median corresponds to 0.89 ha. In the normalization process, the maximum value (1) has been assigned to outliers' values (above 14ha).

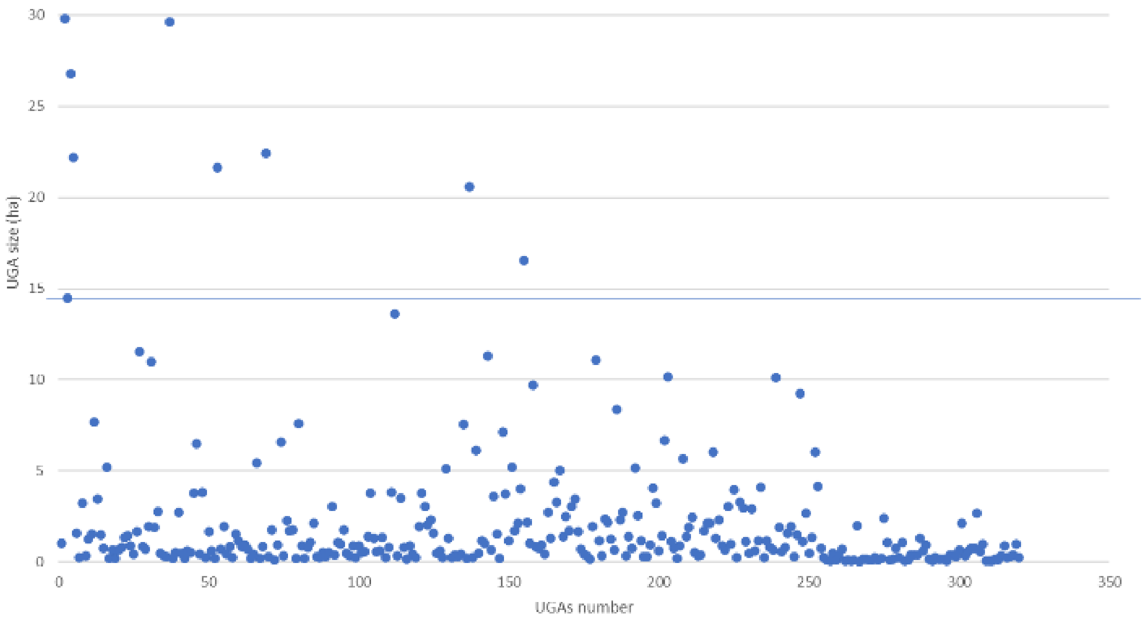


Figure 6-8 Scatter chart of Bologna UGA size, highlighting outlier values

The UGAs considered in this study covered around 7.3 Km², while the accounting of the overall Public green in the city stands around 10 Km² (Comune di Bologna, 2009). This can be explained by the fact that as already mentioned in the introduction, we considered here just a part of the urban GBI accessible through identified access point and suitable for recreational uses. Thus, the green present in the streets, in the roundabouts or in public areas not accessible to the whole public (e.g schools) have not been accounted. UGAs covered around 5% of the overall land and the overall quantity of UGA corresponds to 19.2m²/inhabitant. This is in line with the finding of the Enroute project that affirm that, on average, European citizens have access to about 18 m2 public green space within the boundary of their city (Maes, Zulian, and Thijssen 2019).

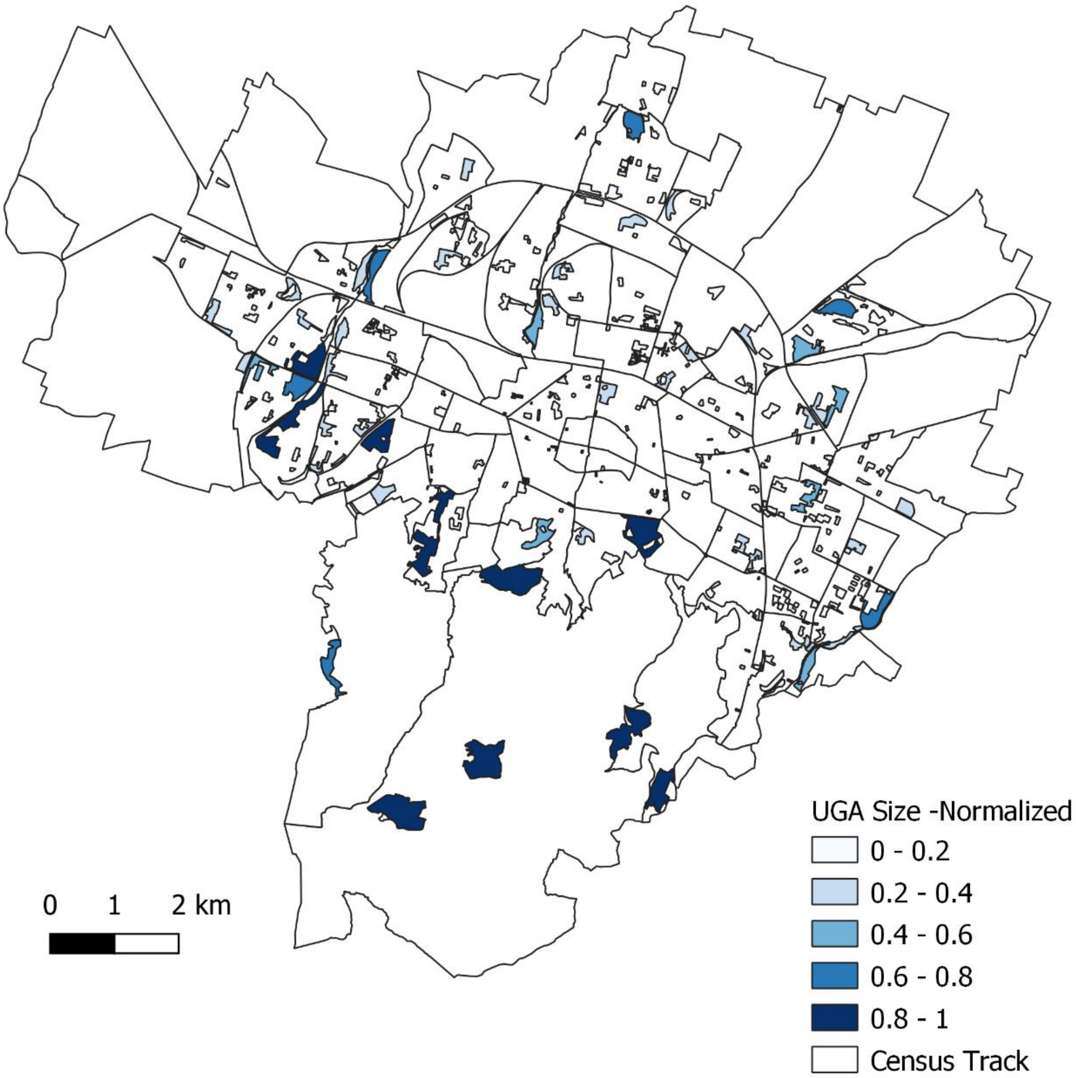


Figure 6-9 UGAs values normalized according to their relative size.

Considering the distribution of UGA areas in terms of their sizes, as already mentioned in the proximity analysis, most of the widest area, (more than 10 ha) are located in the southern hilly part of the city, as show in the map in Fig. 6-9. Also, a significant share of urban green is located at the riverside on the eastern part of the city and at the border line of the south western part. Generally, as also acknowledged in similar studies (Aquino & Gainza, 2014; Tian, Jim, & Wang, 2014), there is a significant gradient from smaller areas in the city centre to wider areas moving out to the peripheric areas.

6.6.2.2 GREEN STEWARDS MAPPING

We mapped Green Stewards (GSs), i.e. social, cultural, sport and community-based organizations operating in the urban UGA, through institutional sources (Iperbole, n.d., Fondazione Innovazione Urbana, n.d.) and through open access maps showing the districts' participatory processes "Laboratori di quartiere" (Fondazione Innovazione Urbana, n.d.). Social media pages of citizens groups or association were also essential for a better understanding of the presence, the typology of activity proposed and their frequency. After this research, we georeferenced all the GSs listed, and we located them within the UGA where they are operating. The features mapped are:

- the number of associations presented in each green area (Fig. 6-10)
- the different typology of activities (social; cultural; educational; environmental; sport; maintenance) and their frequency (Fig. 6-11)

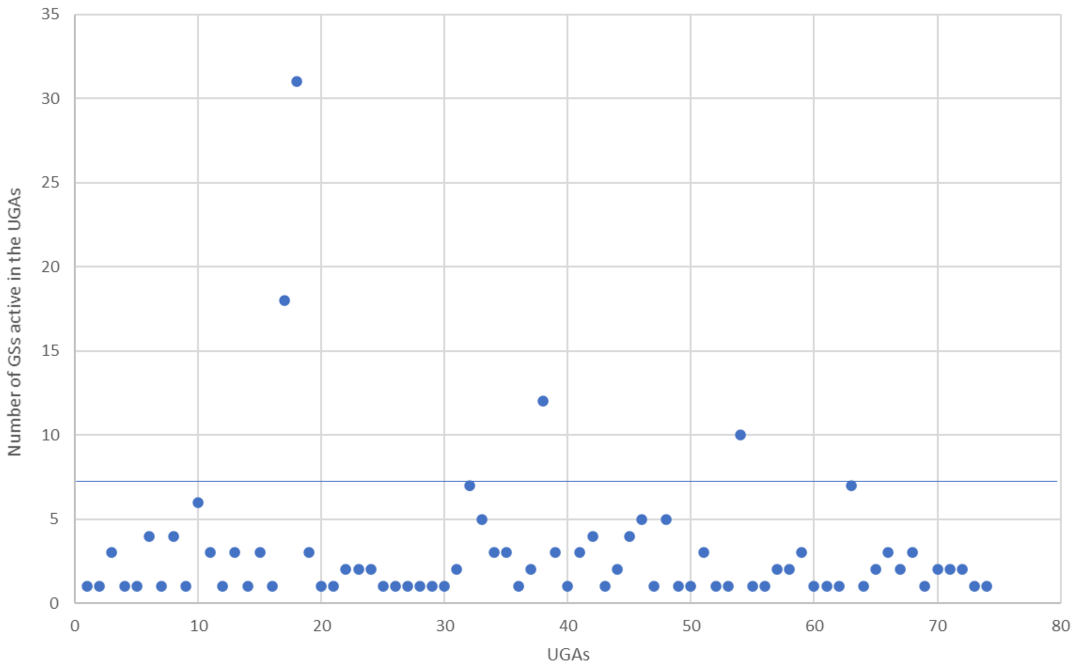


Figure 6-10 Number of Green Stewards active in Bologna UGAs

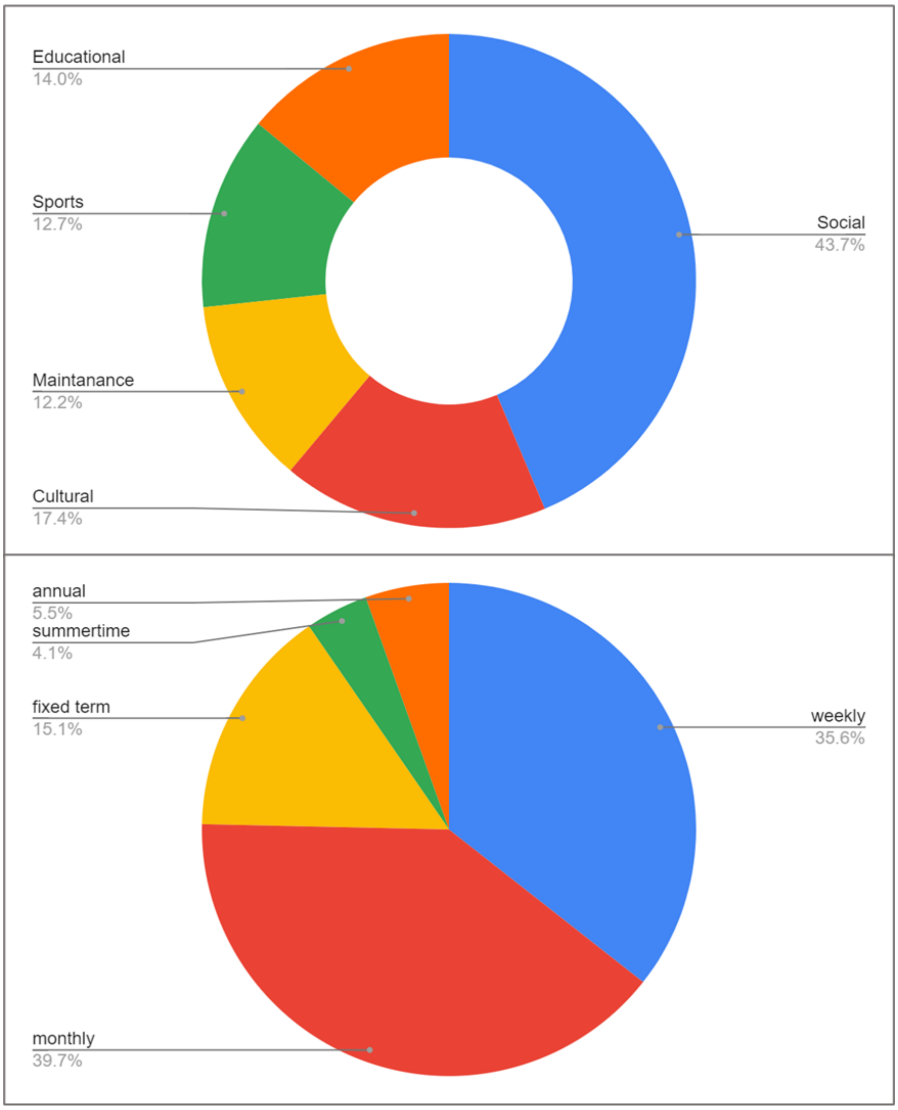


Figure 6-11 Green Stewards active in UGAs, type and frequency of the activity

According to our findings, 221 Green Stewards are active in 72 UGAs of the city. Concerning the activities in place, each GS performs one or more activity in the UGA. In our mapping, we considered all the different activities performed, characterizing them according to their main scope. We mapped a very diverse range of activities going from theatre in UGAs, to sport association performing physical activities (e.g. yoga, hiking, runners, calisthenics, etc.), to food related activities and events (baking breads in a community oven, urban farming, food festival) and educational activities (e.g. children activities in the nature, wild species recognition). For the characterization of the activities, in some cases (i.e theatre representation, cultural activities for migrants' integration, social activities aiming at physical recreation), a single activity has been included into more than one category (i.e social AND cultural). The type of activities mapped well-covers the 6 defined categories, with a predominance of social related activities (39.6%), followed by cultural activities (15.8%). Educational, sport related, and maintenance activities present a similar share of around 11%, while educational follows at last with 9,2%. In absolute terms, we found that almost 500 activities are taking place in Bologna UGAs, with various frequency, with some seasonal event but well-distributed all over the year. Fig. 6-12 presents the distribution of GS in the different UGAs of the city. As for the UGA size normalization, outliers' values have been removed to proceed with the normalization procedure. The results of our mapping exercise do not show a positive direct relation between the number of GSs and the size of the area.

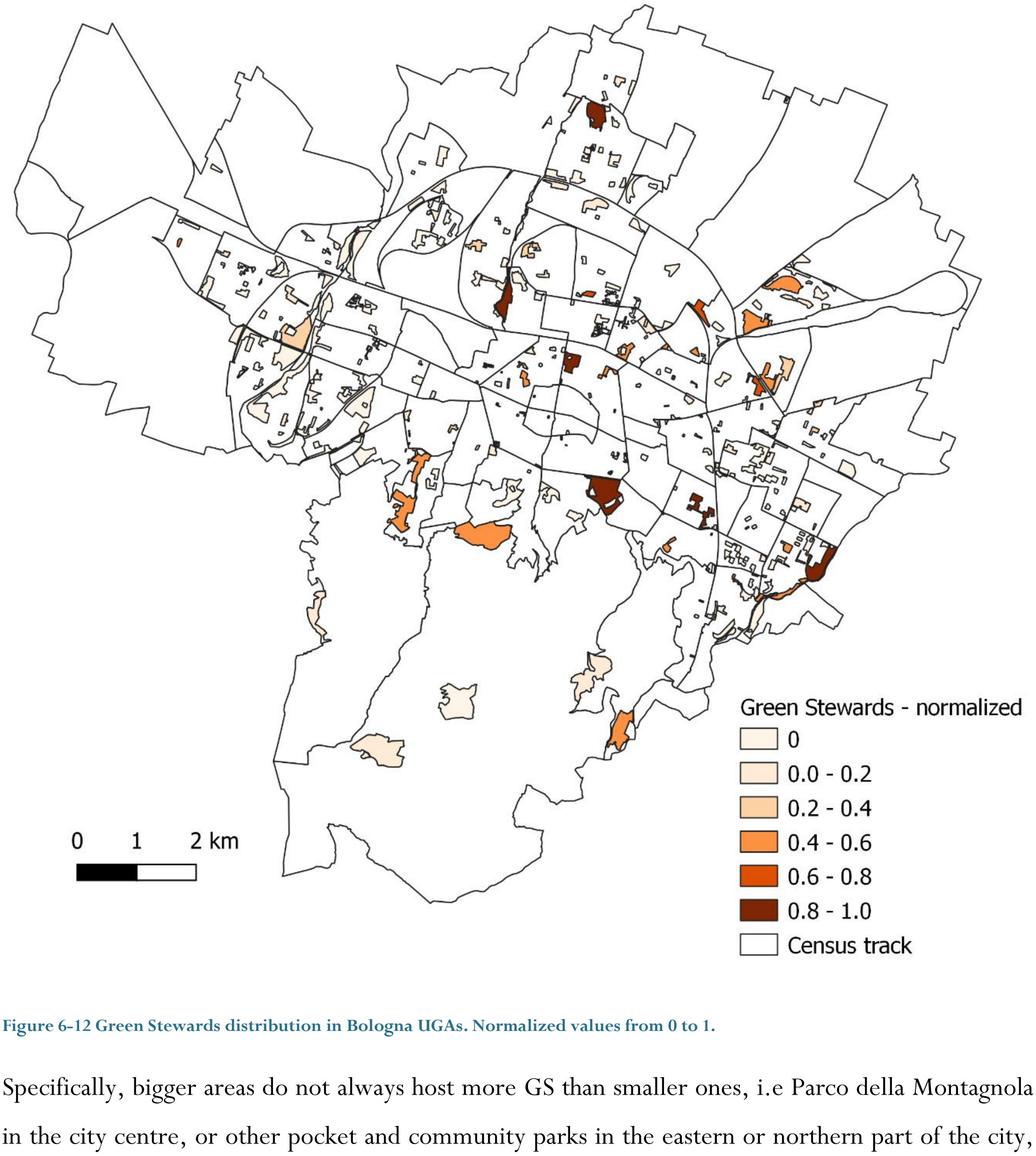


Figure 6-12 Green Stewards distribution in Bologna UGAs. Normalized values from 0 to 1.

Specifically, bigger areas do not always host more GS than smaller ones, i.e Parco della Montagnola in the city centre, or other pocket and community parks in the eastern or northern part of the city, result very active in terms of activities implemented by GSs. Notably, even though we cannot find a clear gradient distribution of GSs within the city, most of UGAs located in the city centres or close to the city centres present high values of GSs (0.6). As for the rest of the city, the riverside areas at the east side of the city lack GSs, while one main UGA, namely Parco dei Giardini, stands out in the north part of the city, hosting a wide range of activities in a peripheral area. Also, on the west side of the map we can find several UGAs with high values of GSs.

6.6.2.3 SPORT FEATURES QUALITY

UGAs sport features have been analysed through the street view navigation of Google maps and further detailed through the reviews left by the users of the parks. Around the half (48.6%) of UGA in the city of Bologna hosts at least one of the mapped sport features (running path; sports fields; hiking trails; children playground; advanced sports equipment; elderly sensitive equipment). As shown in Fig. 6-13, most of the mapped UGAs include running paths (49.2%), followed by sport fields (21%) and children playground (18.3%). Running paths include both formally and informally designed paths. In some cases, running paths have been considered suitable for elderly physical recreation.

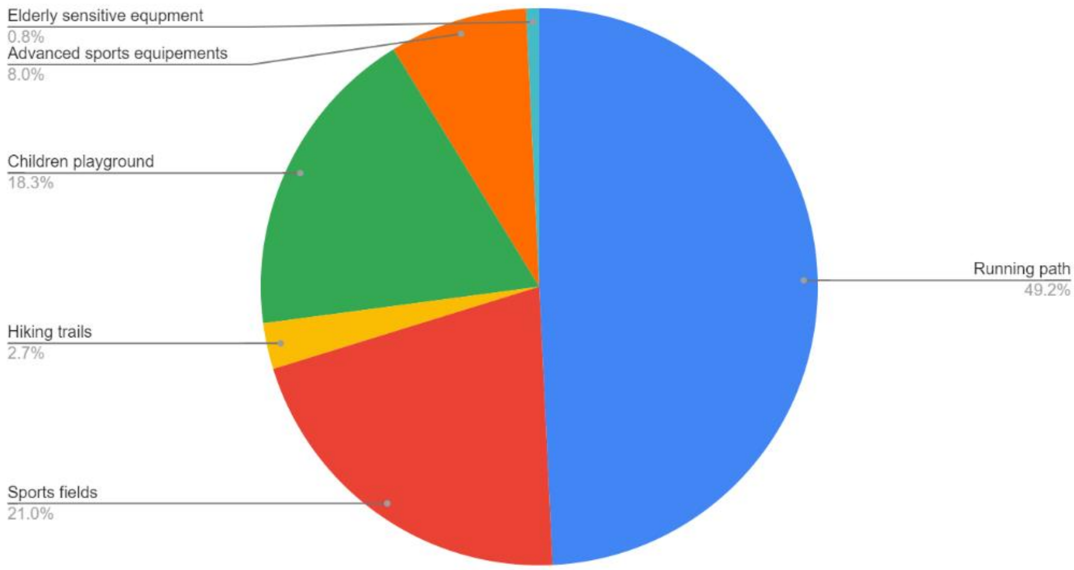


Figure 6-13 Type of sport features mapped in Bologna UGA

This was the case for few UGAs where running paths are wide, with no obstacle along the way and no up-hill rides. As for children playground, we just looked at features facilitating children physical recreation (i.e swings have not been considered).

While 8% of the UGAs presents advanced sport equipment, allowing user to perform free body exercises, thus enabling more vigorous physical activities, just 2 UGAs (0.8%) included elderly-sensitive equipment.

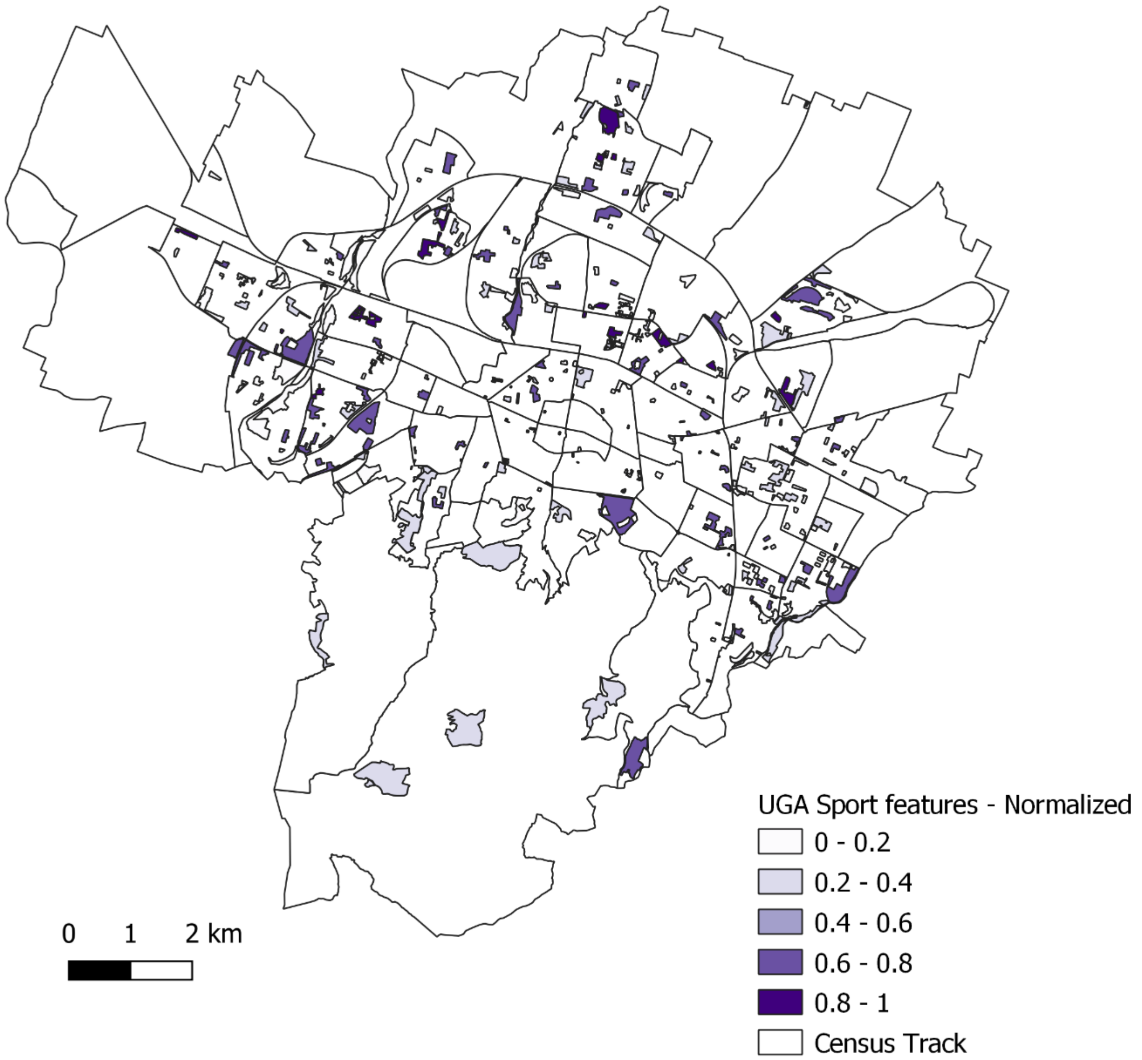


Figure 6-14 Sport feature quality in UGA, normalized values from 0 to 1.

As previously explained, we then assessed the quality of the sport features included in each UGAs, referring to the number of target groups addressed by the sport features identified (No target groups addressed; 0, one target group addressed; 0,4; two target groups addressed, 0,8; three target groups addressed, 1) as shown in Fig. 6-14.

In Bologna 54% of the UGAs do not present any sport features, while 40% of UGAs addressed one or two target groups. Just 18 UGAs (6%of the total) of the city include sport features addressing all the three target groups considered and these areas are mostly distributed in the northern districts of the city. While pocket parks mostly present low-quality or no sport features, interestingly, the dimension of the UGAs does not always correspond with higher quality in terms of sport feature. All the urban parks in the southern part of the city present low-quality value addressing just one target group, and just one of the urban parks located at the riverside includes sport features. Notably, several neighbourhood parks in the northern part of the city present high-quality values addressing 2 or 3 target groups. Last, there are two community parks within the city centre, one of which rather small (1ha), that can address two target groups (children and young adults), while all other UGAs include low-quality features or no features at all. None of the UGA in the city centre and in the southern area of the city address elderly as target group.

6.6.2.4 URBAN RECREATION POTENTIAL INDEX CALCULATION

Aware that the three considered components (size, Green Stewards presence and sport features quality) could assume different weights in the composition of the URPI, within this work we used a simple not-weighted average calculation to define the overall Urban Recreation Potential Index of each UGA of the city. We identified 3 URPI classes (low, medium and high) reclassifying the values obtained for the RPI computation. Specifically, around 67% of all UGAs present RPI values below 0.25 and have been considered within the low-quality class. Medium quality is defined by values of RPI ranging from 0.25 and 0.5 and embraces 26% of UGAs, while just 6% of UGA in Bologna presents an overall high quality described by URPI values over 0.5. The spatial distribution of UGAs quality in the city of Bologna is show in Fig 6-15. Even though quite few UGAs present high quality (6%) the allocation of these UGAs areas is distributed around the city, except for the city centre that include just one high quality UGA, Parco della Montagnola, and one medium-quality area, Parco 11 Settembre. The areas at the south of the city generally presented medium high-quality area, while districts in the north mostly include low quality areas, except from two example of high quality UGAs.

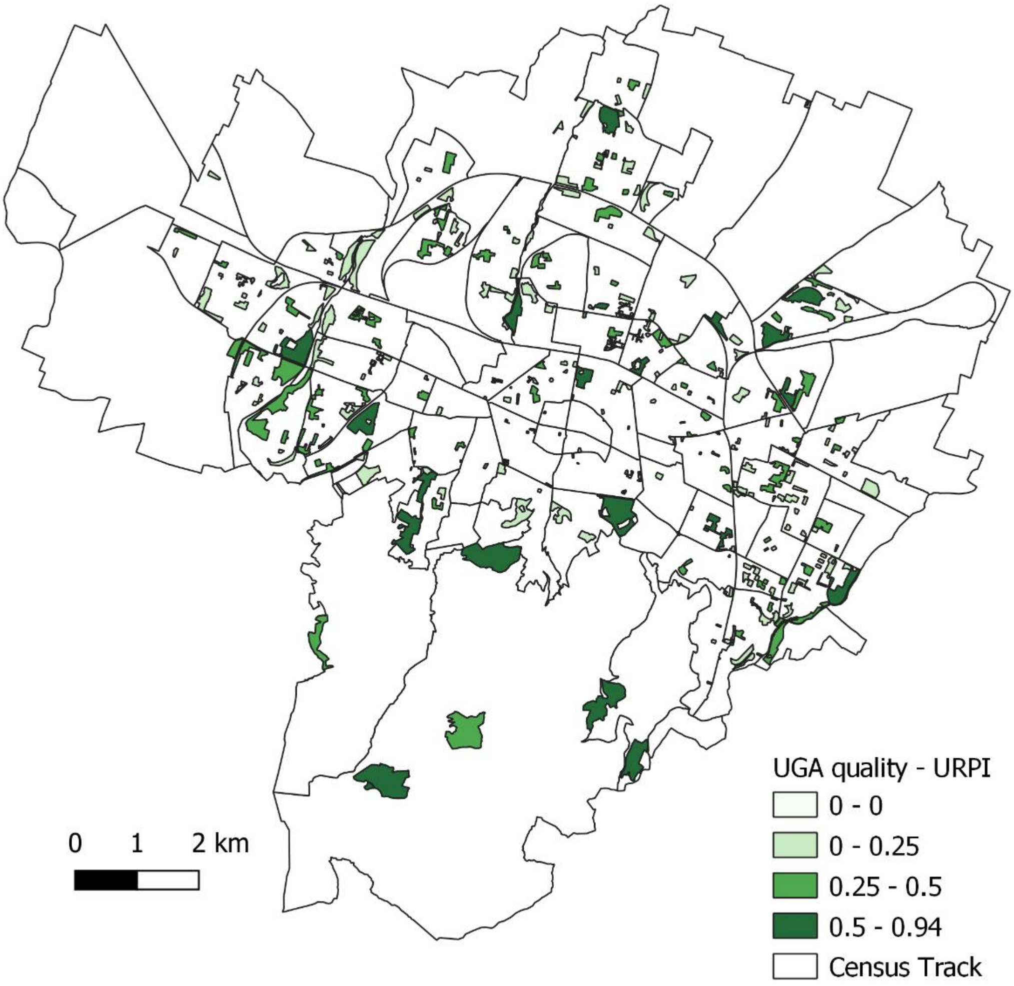


Figure 6-15 UGA quality (URPI) distribution in the UGA of Bologna

6.7 CES SUPPLY DISCUSSION

In accordance with SDG N11.7, each city should work on providing *'by 2030, universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities*'. The recommendation coming from the SDGs and acknowledged by the World health organization (WHO, 2016) was to develop an indicator based on analysis of GIS data on land use and population reflecting proximity of population to urban green spaces. The use of a linear distance of 300 m was suggested as corresponding to approximately 5 min walk along walkable pathways. Despite this acknowledgment of the importance of proximitiy to urban green spaces for considering sustainable a city, so far most of European cities have assessed the presence of green areas through a recognized planning standard, normally consisting in a quantitative indicator, i.e the minimum amount of sq metres of green space per capita - i.e. 6 m^2 per person in the city of Berlin, (Kabisch et al. 2016), 9 m^2 per person in Italy– that doesn't consider UGAs spatial distribution and may result in bias towards certain locations and hence, social groups (Texier, Schiel, & Caruso, 2018). Proximity and accessibility to UGAs for citizens is at present one of the most debated indicators for making cities more equitable, resilient and sustainable. Consequently, this has been the focus of planning and research over recent decades (e.g. Baycan-Levent and Nijkamp 2009; Van Herzele and Wiedemann 2003; Martins and Nazaré Pereira 2018; Quatrini et al. 2016). Within this study we used a network analysis to assess UGAs proximity defining four hierarchical levels of UGAs. While Coles & Bussey, 2000 suggested that an area of approximately 2 ha is the smallest UGA that people regularly want to visit, we noted that the city, even in the densest areas, is generally well-covered by pocket parks (areas < 0.5ha), with increasingly less coverage for bigger areas. Especially in the city centre just 2 areas reach the 2ha sizes, leaving a highly densely populated areas with few small UGAs to be shared by a great amount of people (Aquino & Gainza, 2014; Martins & Nazaré Pereira, 2018). As in other studies, distribution of UGAs is related to geographical position, where the most central parts have less green space than areas nearer the periphery (Aquino & Gainza, 2014; Tian et al., 2014). Even though small parks in the city centre may have a strong connection with the local everyday life (La Rosa, 2014), improving quality of life among beneficiaries, this could lead to overcrowded spaces, with many people requesting and sharing the same services, thus impacting the flow of related benefits. This issue became apparent during the last year due to the COVID-19 restrictions and limited access to UGAs. While people perceived that nature helped them to cope with lockdown measures (Pouso et al., 2021), at the same time people living in crowded city centre may have experienced issues in accessing UGA and in maintaining social distances in overcrowded UGA. Improving access to or increasing the number of UGA in densely populated urban areas with targeted regeneration intervention, should be sought whenever possible, even with temporary intervention and solutions. Acknowledging the densification tendencies in cities in Western countries (Broitman & Koomen, 2020), and that large UGAs are a limited resource in Bologna as well as other similar compact cities, careful decision should be taken over such areas, protecting and enhancing them. In this line, the review by Ekkel and de Vries 2017, acknowledged that cumulative opportunities matter in terms of health-related benefits, requiring accessibility to different UGA sizes and recognizing that bigger UGAs can provide wider health benefits.

While the results of this proximity analysis, at diverse hierarchical distances, can greatly support planners and decision makers over land-use decision providing them evidences of the services needed in different area of the city, the amount of public UGAs do not express the quality of the recreation opportunities that UGAs offer to urban dwellers (Maes, Zulian, and Thijssen 2019). Through the development and the application of the Urban Recreation Potential Indicator (URBI) we aim at supporting planners and decision makers, not only in assessing mismatches, hotspots, and areas of possible regeneration intervention, but also to evaluate UGA quality and multifunctionality. Assessing multifunctionality is considered key as it supports planning practice that considers the ability of UGAs to provide multiple benefits concurrently.

Fair and distributed access to UGAs can improve health and wellbeing by encouraging residents to be more physically active, socialize with neighbours, and enhance community satisfaction. Also, outdoor exercise can provide unique contributions to mental health when compared to exercising indoors (Jennings et al., 2016). Difficulties limiting the access to the use of sports and private recreation facilities (high prices and recreation facility far from the place of residence) could be overcome designing UGAs able to host diversified physical recreation activities thus ensuring inclusive health benefits also to vulnerable social groups (Kruszynska & Poczta, 2020). Well-designed UGAs can encourage physical activity potentially contributing to the health of residents. As presented in the results, just 6% of UGAs of the city include sport features addressing all the three target groups considered. While most of pocket parks present low-quality sport features, in few cases even small UGAs (<2ha) reach medium to high-quality values, suggesting that careful and sensitive UGAs design could support high quality CES provision even in smaller spaces. Also, while children playground and sport features enabling physical recreation of young and adults are sufficiently addressed in the city, UGAs are not adequately including older adults' needs. Even though older adults are more likely to visit UGAs for 'rest and restitution' than the younger age groups (Peschardt et al., 2012), the World Health Organization noted that UGAs could be key in improving age-friendly city. Thus, in an increasingly ageing society, it is necessary to design UGAs for the promotion of healthy ageing boosting healthcare and alleviating medical burdens (Tan, Ka-Lun Lau, Roberts, Tzu-Yuan Chao, & Ng, 2019). Restorative spaces or therapeutical gardens are starting to raise as ageing-friendly UGAs, but the question around the best design solutions for UGAs to enhance inclusive social well-being is still open. In this line, co-designing, or re-designing UGAs with local communities involving older adults (Fumagalli et al., 2020), but also children and other vulnerable groups (Ferreira et al., 2020), could largely contribute to provide better quality UGAs for cities.

According to Rockström, 2015, stewardship of ecosystem services (ES) is one of the greatest challenges for landscape and urban planning in the 21st century, but underlying factors enabling ES stewardship are still poorly understood. Social and institutional processes can significantly influence the perception of ES values in the urban GBI since community management and enhanced property rights stipulate place identity and social cohesion(Andersson et al., 2017). Great attention has been dedicated to urban gardens as *hubs for civic engagement* (Bendt, Barthel, & Colding, 2013; Camps-Calvet et al., 2016) and on citizens as co-creators of public services as community-based initiatives *are often praised for their capacity to enhance legitimacy, solve societal problems and issues, foster (social) innovation and achieve sustainability* (Edelenbos et al., 2020). Nevertheless, ES governance of other UGAs remains rarely explored, whether theoretically or empirically. While several initiatives on co-creation and co-management of UGAs in cities are raising within EU funded projects, one of the main challenges for planners and decision makers would be to operationalize this concept in ways that are meaningful to local stakeholders and useful to foster sustainable management of social-ecological systems (SES) (Barnaud et al. 2018). Within this work, we assume that the presence of community-based initiatives, no-profit organizations or single citizens actions that are actively working on the urban GBI and their management practices influence the perceived quality of urban ecosystems (Joassart-Marcelli, Wolch, & Salim, 2011). We believe that the cultural and social factors involved in such practices underpin the generation and enable the flow of many CES, emphasising the significance that people attach to places. The analysis of Urban Green Stewards provides interesting results on the type and the frequency of the activities taking place in UGAs, thus the level of attractiveness that these places represent for the local communities. In absolute terms, we found that almost 500 activities are taking place in Bologna UGAs, with various frequency, with some seasonal event but well-distributed all over the year. Interestingly the type and the frequency of the activities led by GSs in the city of Bologna does not relate with the size of UGAs. We can then argue the flow of CES facilitated by GSs in urban areas (social cohesion, educational and cognitive development, recreational and cultural services and physical recreation) may not be size-dependent, allowing small UGAs to assume multifunctional values in the urban environment. This assumption should encourage cities to develop dedicate funding and governance models for GSs, enhancing regeneration models that could facilitate CES flows in small UGAs in densely compact city model. This model could largely enable CES related health and wellbeing benefits for the population. In this line, the city of Bologna is an illustrative case since many of the activities mapped in this exercise derived for two participatory processes set up by the city of Bologna. One regards the so-called collaboration pact, a form of Public Private partnership or Public

Public Partnership defined within the Regulation on Public Collaboration for the Urban Commons. The document is mostly relevant for the governance and the management structure of the public spaces and through collaboration pacts, the city council defines and agrees with citizens and organizations (informal groups, NGO's, private entities) management, regeneration and maintenance activities of urban commons (green space, abandoned buildings, squares). Also, the bottom-up participatory process of "laboratori di quartiere" developed through the resources of the participatory budgeting of the city allowed many neighbourhood associations to propose and further kick-off nature-based recreational activities in UGAs. The successful experiences derived from these collaborations might enhance not only the use and the maintenance of the UGAs, but also the flow of related benefits, attracting urban dwellers to UGAs to enjoy a wide range of activities. The type of activities mapped well-cover the 6 defined categories, with a predominance of social related activities (39.6%), thus enhancing social relation and cohesion, followed by cultural activities (15.8%) boosting cultural and recreational services. Notably, in most of the cases maintenance is considered as a side activity, as a necessary condition to make use of the UGAs. Recreational, educational and raising awareness activities, involving a wide range of target groups from children (gardening activities, outdoors schools) to families and adults (learning hiking's, biodiversity walk, natural heritage discovery) and older adults (urban farming, slow walk, soft maintenance work) strongly contribute to enhance the flow of CES. Even though older adults are less keen to frequent UGAs to socialise (Peschardt, Schipperijn, & Stigsdotter, 2012), targeted activities can enhance health and wellbeing of this vulnerable group. Since no preferences or attitude have been assessed in this study, and this leaves spaces for further research, we refer to literature studies that acknowledge that park visitors who engaged in social activities were more likely to have local acquaintances compared to visitors who used parks for non-social reasons (Kaźmierczak, 2013). As acknowledged by McGinlay et al. 2018, the interplay of these cultural practices (activities and interactions) and UGAs are mutually reinforcing in leading to well-being and in supporting the CES co-production models (Langemeyer & Connolly, 2020). At the same time GSs, through the implementation of activities in UGAs, boost social interactions among residents, facilitating CES flows that influence a range of factors that are linked to physical and psychological well-being (Jennings et al., 2016).

To provide a comprehensive assessment of UGAs quality (size, urban Green Stewardship and sport features quality), we developed the Urban Recreational Potential Index. Acknowledging that other valuable approaches such as the ESTIMAP model (Zulian et al., 2013 and Cortinovis et al. 2018) and several other indicators such as naturalness (Arnold et al., 2018; Paracchini et al., 2014), connectivity among UGAs (Rusche, Reimer, & Stichmann, 2019), or structural green space elements (Daniels et al., 2018) could be considered, we believe that the proposed URPI can enhance the understanding of urban dynamics related with the management and the governance of UGAs. The UGAs quality assessment through the developed URPI can support a better understanding and assessment of specific CES - i.e physical and cultural recreation, educational and cognitive development and social relation and cohesion – and the related health and wellbeing benefits. The URPI is intended to support the operationalization of the concept of CES co-production in urban areas, acknowledging that Green Stewards and high-quality sport features can positively enhance human-nature interactions enabling CES flow and related health and wellbeing benefits. Also, based on the results of the case study we may assume that GSs and high-quality sport features can contribute to the overall quality and further usability of UGAs, despite the dimension of the area. While many studies acknowledged size as the main proxy of UGAs quality in cities, we suggest that even pocket and community parks (<2.5ha), if properly equipped, designed and animated by local GSs, can provide a wide range of services to the population. This could be particularly interesting for compact dense cities with low possibility of de-sealing and creating new UGAs (such as many European historic city centre). The URPI can support to showcase a systematic assessment of different functions helping identifying areas where action is needed to increase multifunctionality and/or promote priority functions (Hansen, Olafsson, van der Jagt, Rall, & Pauleit, 2019). Improving existing UGAs to deliver multiple benefits or creating new multifunctional pocket or community park in densely inhabited districts could greatly enhance local quality of life supporting social cohesion and wellbeing. This foreseen a wide and careful knowledge of existing UGAs and the application of the URPI to urban aeras can support this process. Indeed, its application in the city of Bologna showed hotspots where quality should be further improved and purpose governance, planning and financial measures to intervene in this direction. The replicability of the methodology proposed in other urban context would largely support the tailoring and testing of the proposed index for defining UGA quality, opening up to possibilities for its integration into planning practices and tools.

6.8 CES DEMAND RESULTS

6.8.1 POPULATION

Latest available data on the overall population resident in the municipality of Bologna reports 391.984 people living in the city (2020), with around 53% of women and 47% of men. Among those, as shown in Fig. 6-16, around 30% of the population are adults (45-64), followed by the 21% of younger adults' group (30-44). Older adults over 65 years old constitute the 24% of the population while youngsters (15-29) represents just the 14%, followed by the children group (0-14) that accounts for the 12% of the total share (Città Metropolitana, n.d.).

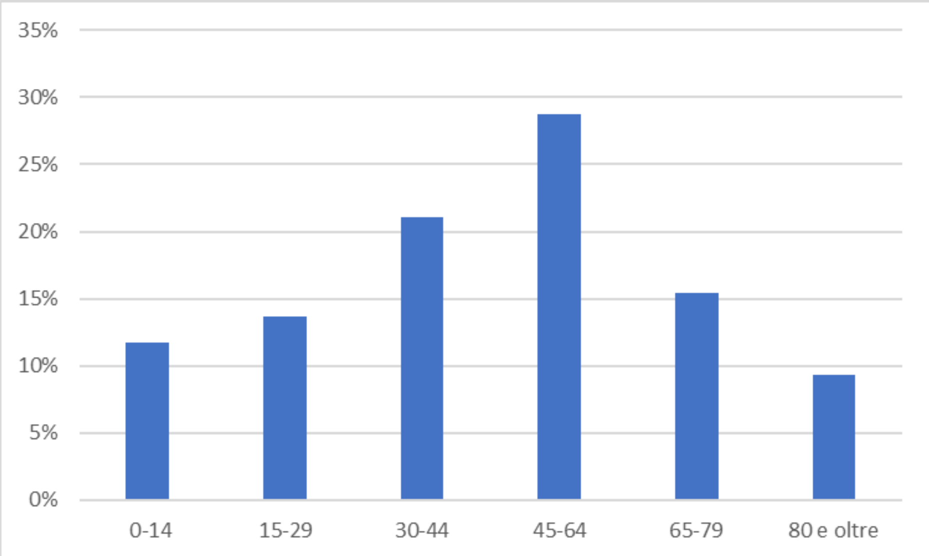


Figure 6-16 Distribution of the age groups of the resident population in Bologna

According to the latest data coming from the Italian Statistics institute, the distribution of the age groups of resident population in Bologna is in line with the overall data for Italy (ISTAT, 2011). Compared with the beginning of 2010, there is an increase average both regarding the mean age of the population (from 44.5 to 46 years old) and both concerning the share of over 75 years old people (from 11 to 13%). This data support the current increase in the Italian trend, where elderly population (aged 65 and over) was 20.1% in 2007, 22.8% in 2019, and it is projected to be 24.2% by 2025 (Fumagalli et al., 2020).

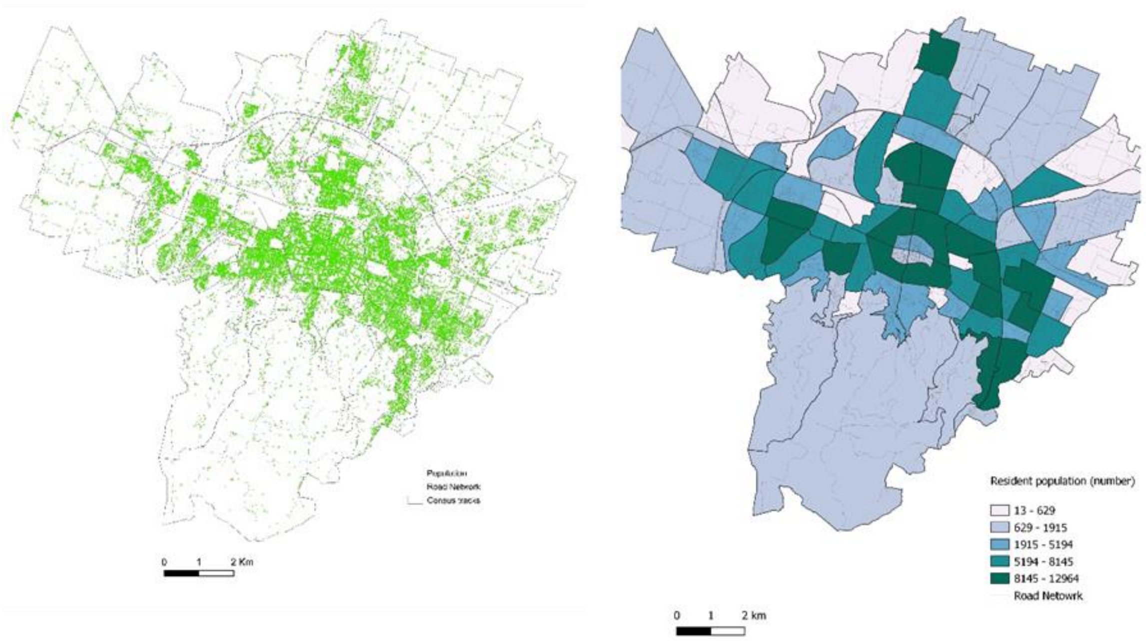


Figure 6-17 Georeferenced population and number of resident population per census track

Georeferenced population data have been obtained from the municipality of Bologna, as available open data are presented in aggregated levels not useful for the scope of the analysis. The data obtained contain georeferenced information about the population living for each house number of the city (Fig.6-17). As we already noticed in water demand within regulating services analysis, where domestic demand was very high in city centre and bordering districts, city centre and bordering areas host a great share of the population, together with more peripheral census track at the eastern and western area of the city. The southern part (mostly wooded and hilly) the north east area (mostly industrialized) and the extreme western side (the urban a peri-urban agricultural land) host a relatively low share of residents.

6.8.2 VULNERABILITY

To better understand and evaluate CES demand it is necessary to investigate not just the amount of citizens living in a specific area, but also population needs, preferences and perceptions (Andersson et al., 2015; Bertram & Rehdanz, 2015). The literature defines children, the elderly, and low-income neighbourhoods as having the greatest needs for parks within walking distance (Talen 2003; Wolch, Wilson, and Fehrenbach 2005). The vulnerability index, developed by the municipality of Bologna (Comune di Bologna, 2018) included most of these indicators (as explained in Section 7.2.2) and it was then considered suitable for our analysis. The values of the vulnerability index have been reclassified defining three classes of vulnerability (low, medium, and high) associated with the city

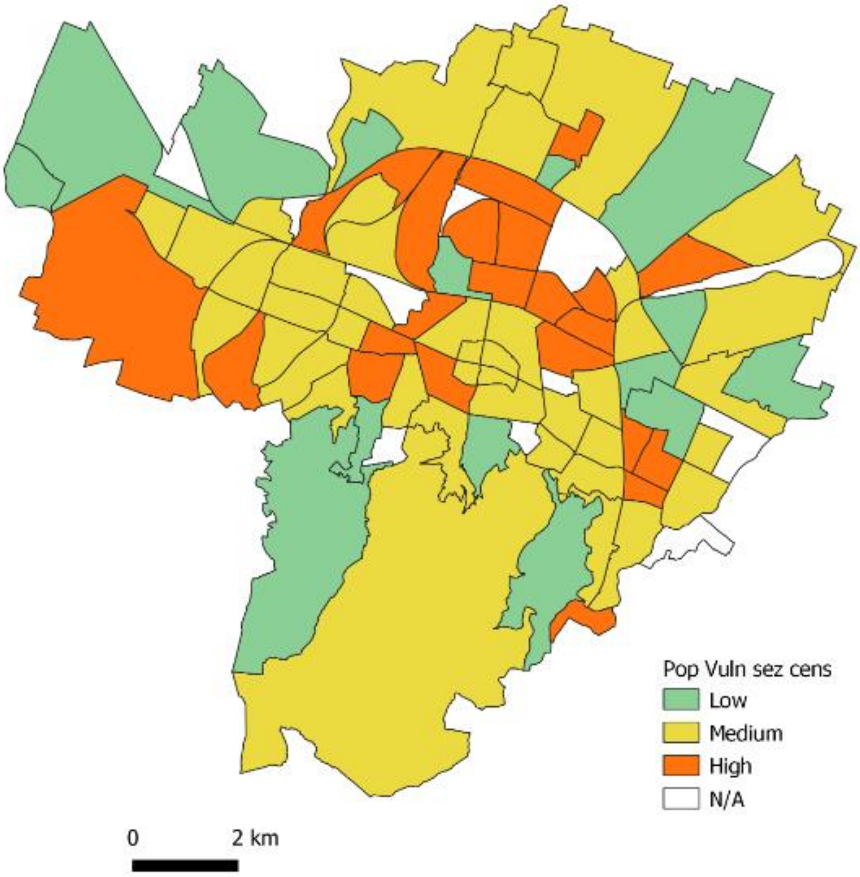


Figure 6-18 Population vulnerability - Census Tracks class

census track. Fig. 6-18 shows an irregular distribution of vulnerability classes within the city, with a higher concentration of high vulnerability census tracks in the first periphery line heading north from the city centre. Looking at the single indicators composing the vulnerability index (Comune di Bologna, 2018), these areas are highly vulnerable mostly due to demographic (high share of elderly) and social (high share of migrants, foreign minors' residents, lower educational background) and economic indicators (lower income). Overall, the city centre presents a medium value of vulnerability mostly given by a high social vulnerability (high share of elderly living alone, high share of empty or rented houses). Even though economic indicators are in balance or above the average values, areas at the eastern part of the city present medium to high vulnerability given by demographic characteristics (high share of elderly among residents and negative variation of resident population over the last 5 years).

6.9 CES SUPPLY AND DEMAND MISMATCHES RESULTS

6.9.1 ACCESSIBILITY

Accessibility to UGAs has been calculated considering the results of the proximity analysis and overlapping to it the georeferenced population layer. At this stage in the accessibility computation, we just considered one fixed network distance (300m) for all the 4 types of UGA defined within the city. Fig. 6-19 shows the population served (green dots) non-served (red dots) by UGA (300m) in the city of Bologna. Overall, the ratio of inhabitants who find at least one UGA within 300m is approximately 71%. This means that around the 30% of city dwellers, approximately 115.000 people, do not have access to any kind of UGA within 300 m network distance from their place. The map shows critical areas at the core of the city centre, mostly located in southern east part of the centre, but also at more peripherical areas. Remarkably, also the southern part of the city, mostly covered by wooded and green areas, leaves most of its resident population not served by UGAs.

Also, at the east side of the city, mostly covered with agricultural land, the lack of UGAs accessible results in mismatches concerning the CES supply and demand of this area. As for the rest of the city, very dense areas at the border of the city centres also present notable mismatches and high range of population not served by any UGA.

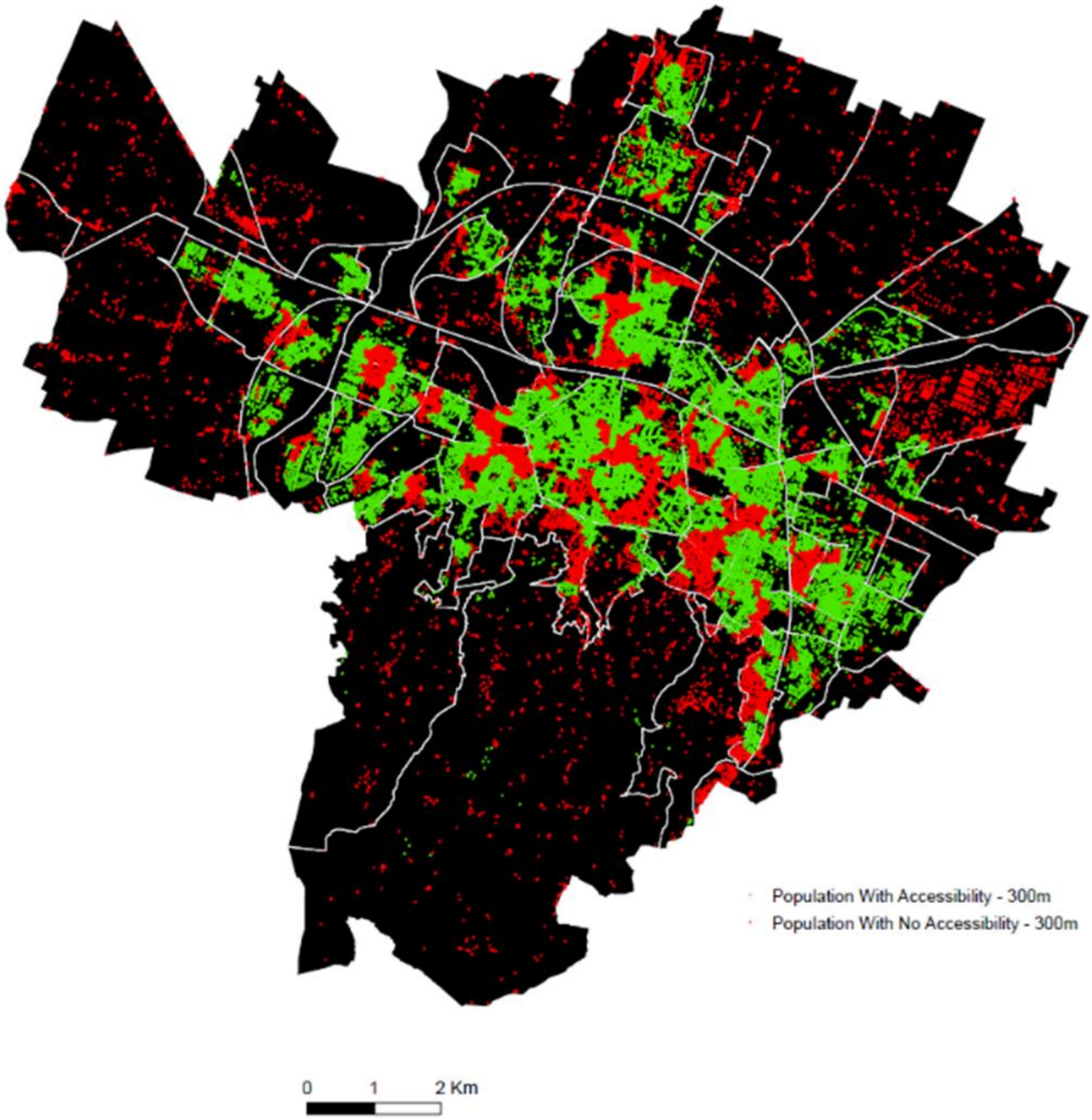


Figure 6-19 Population served (green dots) not served (red dots) in the city of Bologna

While Figure 6-19 already provides some useful information to better evaluate accessibility at a spatial level and to support planners and decision makers in the identification of hotspots of mismatches, we also evaluated accsssibility at census track level to be able to compare the different areas among the city (Fig. 6-20). Three accessibility classes have been defined as follows:

- low accessibility (<50% of CSpopulation has access to UGAs within 300m),
- medium accessibility (50% to 70% of CSpopulation has access to UGAs within 300m)
- high accessibility (>70% of CSpopulation has access to UGAs within 300m)

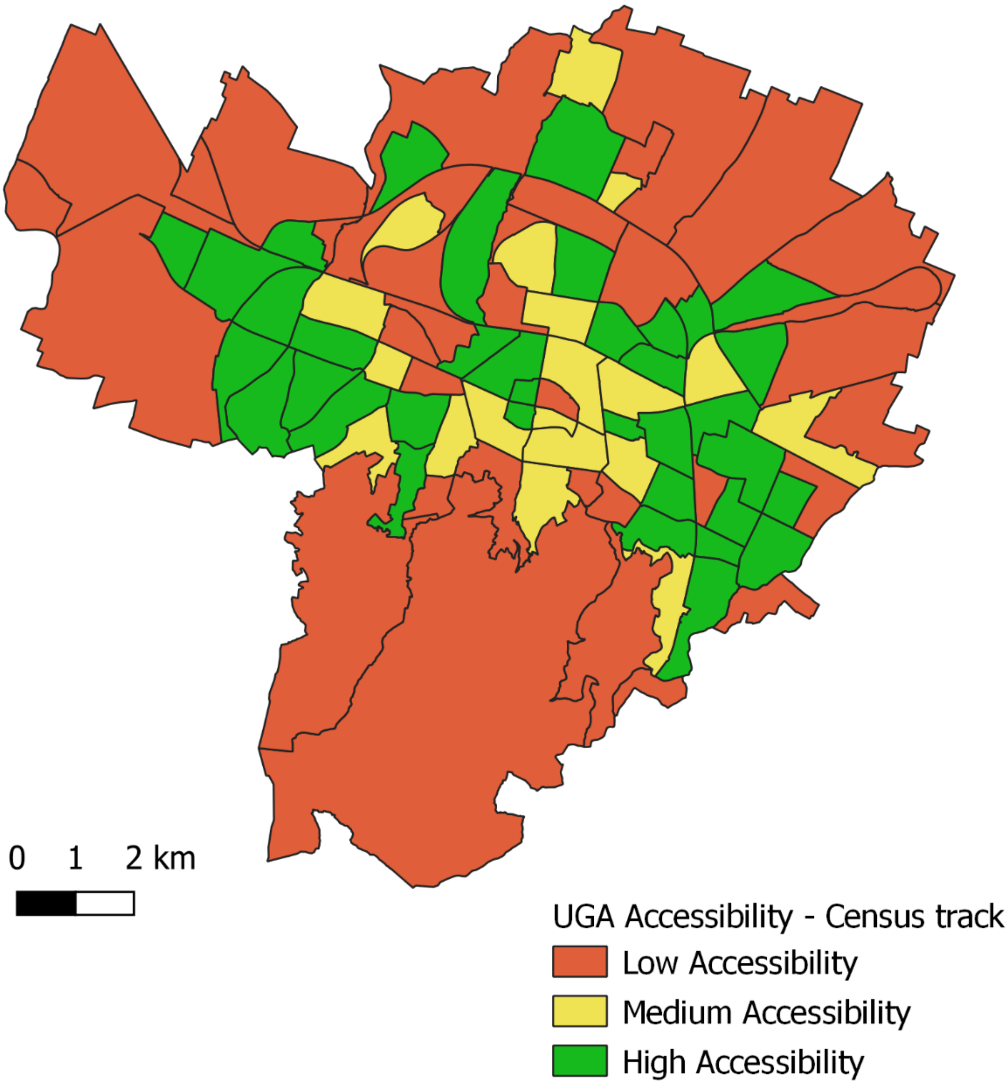


Figure 6-20 Accessibility classes per census track (300m network distance)

The distribution of the different accessibility classes highlights that Bologna city centre generally presents low to medium accessibility to UGAs, except from one area, at the north west where a high level of accessibility is assessed. Around 60% of the inhabitants of the city centre, one of the mostly densely populated area of the city do not have access to any UGA within 300m from their house. On the other side the other high populated areas of the city on the west side and the south east areas, present medium to high accessibility values, also having access to bigger areas (i.e urban parks and neighbourhood park) within 300 m. The southern area of the city, despite the high share of urban parks, present low accessibility. Because of a low-density population, few people fall into the 300m network distances from the urban parks present in this area, that resulted to be inaccessible for most of the population.

6.9.2 DISTRIBUTIONAL JUSTICE

As detailed in Section 6.5.2, we performed two different analysis to assess distributional justice within the city. While population vulnerability and UGA quantity (accessibility) have already been associated with the related census track, to perform the Chi square test and the weighted spatial regression we distributed UGA quality (URPI) in census track according to the methods described in Section 6.3.2. As previously explained, each variable was normalized (0-1) and further divided into three classes, low, medium and high to perform the Chi square test.

Figure 6-21UGA Accessibility, Population Vulnerability and UGA quality (URPI) per census track

The Chi Square test was first performed using the discrete values of accessibility and vulnerability. The results can be considered statistically relevant (p-value = 0.003264) and as shown in Table 6-5. Results show that high-vulnerable areas do not present shortage in terms of UGA quantity. Notably, highly vulnerable areas present a bigger number of highly accessible UGA than those with medium or low level of accessibility (11n), and lowly vulnerable areas report a bigger number of lowly-accessible UGA, than those with high or medium level of accessibility.

Table 6-5 Chi-square test results: Accessibility and vulnerability

	High Accessibility	Medium accessibility	Low Accessibility
High vulnerability	11	4	7
Medium vulnerability	19	13	10
Low vulnerability	5	2	8

We then reiterated the test using vulnerability and UGA quality (URPI) as entry variables. Most of the census tracks presenting high vulnerability values are related with low UGA quality (13n) and none of the highly vulnerable area has access to high UGA quality. On the other side, 5 census tracks with low vulnerability can access high quality UGA (Table 6-6). Generally, medium to high-vulnerable census tracks can access either low or medium UGA quality. Also, in this case results can be considered statistically significant (p-value = 0.01158).

Table 6-6 Chi-square test results: UGA quality and vulnerability

	High UGA quality	Medium UGA quality	Low UGA quality
High vulnerability	0	9	13
Medium vulnerability	2	18	22
Low vulnerability	5	2	8

The results of the Chi-square test have been used as an entry point of the spatial analysis. Indeed, the Chi square test acknowledges that the city of Bologna does not present valuable distributional injustice in relation to access to UGA. Nevertheless, there could be a spatial relation between vulnerability and UGA quality, acknowledging that highly vulnerable population, i.e. with higher needs, does not have access to high quality UGA and, thus, result excluded from the multifunctional flows of benefits provided by such areas. After performing the autocorrelation of the residuals from the OLS analysis, the pattern does not appear to be significantly different than random, so we can assume that we did not overlook any explanatory variable that has a spatially relevant distribution.

Also, confirming the results of the Chi-square, the OLS reports a weak statistical significance for both variables, with a stronger trend toward negative correlation between vulnerability and UGA quality. Even though the statistical significance for this variable is slow and further analysis should be performed (e.g. disaggregating the vulnerability index), spatial analysis confirmed the hypothesis that higher vulnerability census track tends to have access to lower UGAs quality. Departing from this premises, we performed the Geographical Weighted Regression, that illustrates that UGA quality has a strong explanatory value for the vulnerability.

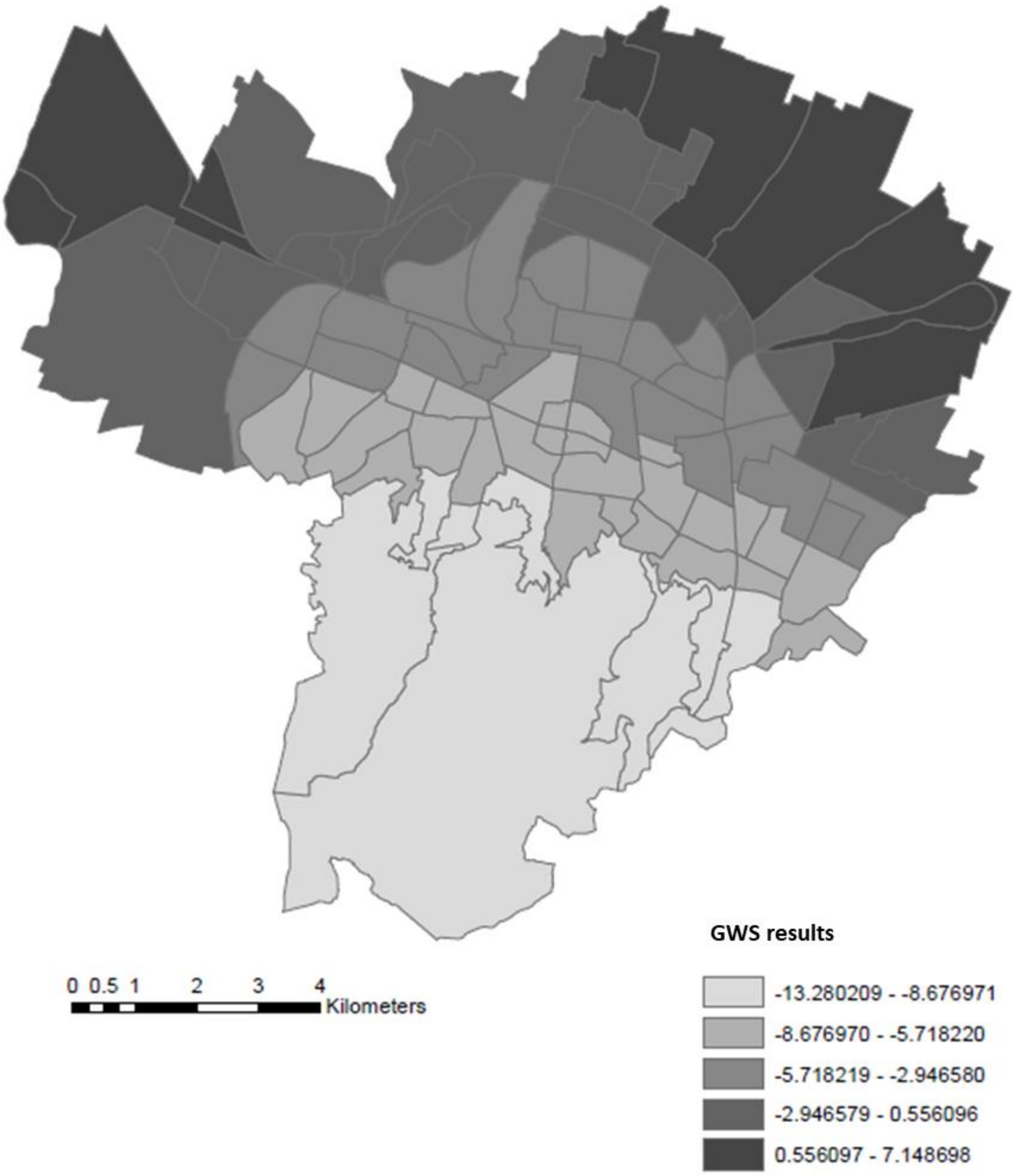


Figure 6-22 Geographical Weighted regression results

Figure 6-22 shows the spatial distribution of the explanatory values of the UGA quality in relation with vulnerability. UGA quality better explains vulnerability in the northern areas of the city, with lower values in the southern part. This spatial distribution may acknowledge the spatial correlation among higher vulnerability and lower quality areas in the northern areas of the city.

6.10 CES SUPPLY AND DEMAND MISMATCHES DISCUSSION

This section examined relevant mismatches and correlation between CES supply and demand in the city of Bologna and it attempts to present an application of a spatially explicit assessment of urban outdoor recreation distribution thus advancing knowledge in this field.

Accessibility is a crucial precondition to enhance the flows of CES related benefits and guaranteeing accessible UGAs to urban dwellers is also among the main target of SDG11. In the analysed case study about 30% of residents do not have access to any UGA within the 300 m network distance considered in the analysis. The GIS application demonstrated to be a useful monitoring tool to visualize the accessibility to UGAs and to support planners and decision makers identifying mismatches between supply and demand for related CES. Comparing it to other case studies (Quatrini et al., 2019; Šiljeg, Marić, Nikolić, & Šiljeg, 2018; Van Herzele & Wiedemann, 2003), the accessibility values are quite high (70% of the population having access to UGAs within 300m from their home), thus acknowledging an overall good level of accessibility to UGAs in the city. Nevertheless, several non-served hotspot areas can be identified through the accessibility analysis, both in the city centre (see also Wen, Albert, and Von Haaren 2020) and some peripheral areas.

Departing from the accessibility and the UGA quality analysis results, we then looked at the population needs in terms of CES demand. The literature defines children, older adults, and low-income people as having the greatest needs for UGAs within walking distance (J. Wolch et al., 2005). For this reason, we have used the population vulnerability index to assess whether vulnerable social groups have sufficient and equitable access to UGAs (Wüstemann, Kalisch, & Kolbe, 2017). Moreover, within this study we focused the attention over the distributional aspect of UGA quality (URPI) and population vulnerability. Needs-based assessments can serve practical purpose by targeting a public good, in this case UGAs, to those groups (because of limitation based on age, ability, or resources) who are most likely to use it or need access to UGAs within walking distances (Boone, Buckley, Grove, & Sister, 2009). While several authors described the relation among quantity and distribution with vulnerable social groups (Dempsey, Brown, & Bramley, 2012; Kabisch & Haase, 2014; Wüstemann et al., 2017) finding contrasting results, to our knowledge there is no previous research that explicitly links UGAs quality and population vulnerability. Results in the city of Bologna show no correlation among vulnerability and accessibility, while significant results highlight a negative relation between vulnerability and UGA quality, meaning that at higher vulnerability corresponds lower UGA quality and vice versa. Based on the assumption that high quality UGAs (based on the developed URPI) provide multiple functions and multiple benefits through the co-production paths enhanced by Green Stewards and high-quality sport feature, we could then assume that in the city of Bologna such benefits are not fairly distributed among the population. Green Stewards develop, among other, activities aiming at cultural integration and social cohesion (i.e laboratory and theatre with migrants in UGAs, activities targeting children or urban farming addressing elderly) and could largely support the distribution of benefits to more vulnerable social groups. At the same time high-quality sport features addressing all the different target groups would make CES flow inclusive and distributed. Through this assessment, we acknowledge potential injustice in the access and flows of CES, that could be addressed without creating new UGAs, but rather improving quality of existing UGAs. In our view, regeneration actions aiming at improving quality of UGAs within highly vulnerable census tracks would largely support a just and fair distribution of CES related benefits in the city, contributing to the overall objective of a sustainable city life. In this light, as already mentioned in the recognition of the role of Green Stewards, delegate power to other actors (formal and informal groups of people, NGOs) which are directly interested in shaping green and recreational spaces (Biernacka and Kronenberg 2018), their quality and their greater accessibility (Colding and Barthel 2013), would largely support CES co-production and relevant flow of benefit. As previously described, this practice is already acknowledged and operationalized in the city of Bologna through the participatory budget and the collaboration pacts that can be considered as an expression of procedural justice (Low, 2013). Nevertheless, according to the results of our analysis, high-vulnerable areas of the city would still need a further integration of such processes, with the aim of increasing UGA quality in those areas. We recognize that one of the challenges to balancing these inequalities is the risk that increasing or improving UGAs in highly vulnerable areas can lead to higher housing prices and thus a shift to residents with higher income (Wolch, Byrne, and Newell 2014), resulting in green gentrification processes (Anguelovski, Connolly, Masip, & Pearsall, 2017). Nevertheless, we acknowledge that while meeting the expectations of all social groups in the city is hardly possible, the main priority should be given to satisfying the needs of the most vulnerable inhabitants (Raymond, Gottwald, Kuoppa, & Kyttä, 2016), thus careful planning to enhance UGAs quality in highly vulnerable areas should be sought, regulating speculation mechanism that could support gentrification process in such areas.

6.11 CULTURAL ECOSYSTEM SERVICES CONCLUSIONS

UGAs play a key role in the development of compact sustainable and resilient cities by providing a variety of ecosystem functions and services (Daniels et al., 2018). Facing the issues of satisfying the needs of high-density population in compact cities, it becomes increasingly important that UGAs are designed to meet the various needs and demands within an urban environment, considering the ecological, economic and social constrains and requests of complex socio-ecological systems. We proposed to assess Cultural ES in a multifunctional way considering i) qualitative CES supply (through the proximity analysis and implementation of the URPI) ii) quantitative CES supply (through accessibility analysis) iii) quantitative and qualitative CES demand (population and vulnerability) iv) CES Supply-demand mismatches in terms of accessibility and distributional justice analysis.

Through the inclusion of size, sport features quality and Green Stewards role in facilitating and co-producing CES in urban areas, we argue that the URPI can be used as a quality standard criterion in UGA planning and assessment, that together with accessibility and quantitative criteria could support planning of multifunctional and attractive UGAs. In this line we argue that quantitative criteria should be applied together with quality criteria as green space of poor quality does not provide the same benefits' flow and is less used by the population (Byrne, Sipe, & Searle, 2010). Moreover, this quality criteria should be applied in conjunction with functional criteria of GBI and NBS planning for regulating ES as presented in previous results and discussed in the following conclusion.

Basing on the results of our case study, we argue that accessibility of UGAs in the city could be improved addressing:

i) <u>provision of new UGAs</u>; the creation of brand new, multifunctional NBS could be hard in some compact city at least in some specific areas of the city, i.e city centre in the case of our case study. City authorities could co-build new multifunctional micro-scale UGAs (pocket park or community park) (Ye et al., 2018) in urban dense environment, as they can provide diverse CES to the population, as demonstrated in our URPI assessment. Also, as acknowledge by Biernacka and Kronenberg 2018 it would be crucial to determine which UGA are private, which belong to the city, but whose access is currently neglected or underused and which have unresolved legal status, keeping or making them available, accessible and attractive. Also, further mapping and analysis of informal UGAs such as brownfield or previous rail network or also identification of areas of possible de-sealing in the city would largely contribute to improve UGAs provision and accessibility.

We also argue that developing innovative governance and funding scheme involving Green Stewards, in the form of organizations or private citizens, would support and largely improve current accessibility assessment. As Colding and Barthel 2013 pointed out proper incentives to owners of private gardens who grant other users access to their gardens could be a successful scheme to engage into share management of UGAs. Last, explicitly referring to the case of the city of Bologna, some public UGAs, such as the Botanical gardens or other UGAs owned by the university or the city council into city centre could be open to the public, enhancing the idea of UGAs as urban commons.

ii) improve access to existing UGAs; local authorities should enhance access to existing UGAs using green corridors to connect different UGAs, increasing access points and current road network and public transport (Wen et al., 2020).

Overall, also building on Mörtberg et al., 2017 and (Rutt & Gulsrud, 2016), the proposed methods for the analysis and mapping of CES will support local authorities in:

i. Understanding, preserving, and maintaining current UGAs
ii. Boosting the development of pocket park in densely built areas with high need, developing small UGAs multifunctionality through their quality enhancement (Peschardt et al. 2012)
iii. Assessing alternatives in redevelopment areas or urban voids prioritizing the development of UGAs, if CES mismatches are highlighted in such areas
iv. Enhancing quality of existing green space through inclusive co-design of UGAs (Tozer, Hörschelmann, Anguelovski, Bulkeley, & Lazova, 2020), e.g. in relation to sport features, and boosting innovative governance models and funding scheme to foster green stewardship of UGAs
v. Reflecting on mapping properties rights of not accessible UGAs areas, mostly where deficiencies of CES is highlighted (Biernacka and Kronenberg 2018)
vi. Greening road and cycle path to provide green connections among different areas and improve UGAs accessibility
vii. Boosting the understanding of cities as complex socio-ecological system, providing solutions to partly address social vulnerability through greening intervention and UGAs quality enhancement, addressing and re-distributing ES benefits through the city

Even though further work would be needed to better assess declared needs and willingness of local population in terms of citizens' demand and perception of CES, to tailor and integrate the URIP with other potential indicators, and to include economic assessment and analysis, we argue that the proposed method not only cover and integrate the social and ecological dimensions but also provide flexibility in spatial assessments, thus resulting in an effective instrument for planners and decision makers. As Andersson et al. 2015 stated we firmly believe that focusing on high quality provision of CES 'can be a good starting point for increasing the awareness among urban residents of the importance of ES. Thus, since CES are often generated inter-dependently with other critical ES engaging people in the stewardship of CES could provide increased awareness of the benefits of a larger group of urban non-cultural ES'.

LIST OF REFERENCES

Albert, C., Galler, C., Hermes, J., Neuendorf, F., Von Haaren, C., & Lovett, A. (2016). Applying ecosystem services indicators in landscape planning and management: The ES-in-Planning framework. *Ecological Indicators*, *61*, 100–113. https://doi.org/10.1016/j.ecolind.2015.03.029

Andersson, E., Enqvist, J., & Tengö, M. (2017). Stewardship in urban landscapes. *The Science and Practice of Landscape Stewardship*, 222–238. https://doi.org/10.1017/9781316499016.023

Andersson, E., Tengö, M., McPhearson, T., & Kremer, P. (2015). Cultural ecosystem services as a gateway for improving urban sustainability. *Ecosystem Services*, *12*, 165–168. https://doi.org/10.1016/j.ecoser.2014.08.002

Anguelovski, I., Connolly, J. J. T., Masip, L., & Pearsall, H. (2017). Assessing green gentrification in historically disenfranchised neighborhoods_ a longitudinal and spatial analysis of Barcelona. *Urban Geography*, *39*(3), 458–491.

Aquino, F. L., & Gainza, X. (2014). Understanding density in an uneven city, Santiago de Chile: Implications for social and environmental sustainability. *Sustainability (Switzerland)*, *6*(9), 5876–5897. https://doi.org/10.3390/su6095876

Arnold, J., Kleeman, J., & Christine, F. (2018). A differentiated spatial assessment of urban ecosystem services based on land use data in Halle, Germany. *Land*, *7*(101).

Barnaud, Cécile, & Antona, M. (2014). Deconstructing ecosystem services: Uncertainties and controversies around a socially constructed concept. *Geoforum*, *56*, 113–123. https://doi.org/10.1016/j.geoforum.2014.07.003

Barnaud, Cecile, Corbera, E., Muradian, R., Salliou, N., Sirami, C., Vialatte, A., … Antona, M. (2018). Ecosystem services, social interdependencies, and collective action: A conceptual framework. *Ecology and Society*, *23*(1). https://doi.org/10.5751/ES-09848-230115

Baró, F., Calderón-Argelich, A., Langemeyer, J., & Connolly, J. J. T. (2019). Under one canopy? Assessing the distributional environmental justice implications of street tree benefits in Barcelona. *Environmental Science and Policy*, *102*(June), 54–64. https://doi.org/10.1016/j.envsci.2019.08.016

Baycan-Levent, T., & Nijkamp, P. (2009). Planning and Management of Urban Green Spaces in Europe: Comparative Analysis. *Journal of Urban Planning and Development*, *135*(1), 1–12. https://doi.org/10.1061/(asce)0733-9488(2009)135:1(1)

Bendt, P., Barthel, S., & Colding, J. (2013). Civic greening and environmental learning in public-access community gardens in Berlin. *Landscape and Urban Planning*, *109*(1), 18–30. https://doi.org/10.1016/j.landurbplan.2012.10.003

Bertram, C., & Rehdanz, K. (2015). Preferences for cultural urban ecosystem services: Comparing attitudes, perception, and use. *Ecosystem Services*, *12*, 187–199. https://doi.org/10.1016/j.ecoser.2014.12.011

Bieling, C. (2014). Cultural ecosystem services as revealed through short stories from residents of the Swabian Alb (Germany). *Ecosystem Services*, *8*, 207–215. https://doi.org/10.1016/j.ecoser.2014.04.002

Biernacka, M., & Kronenberg, J. (2018). Classification of institutional barriers affecting the availability, accessibility and attractiveness of urban green spaces. *Urban Forestry & Urban Greening*, *36*, 22–33. https://doi.org/10.1016/J.UFUG.2018.09.007

Boone, C. G., Buckley, G. L., Grove, J. M., & Sister, C. (2009). Parks and People_:An Environmental Justice Inquiry in Baltimore, Maryland.pdf. *Annals of the Association of American Geographers*, *99*(4), 767–787.

Broitman, D., & Koomen, E. (2020). The attraction of urban cores: Densification in Dutch city centres. *Urban Studies*, *57*(9), 1920–1939. https://doi.org/10.1177/0042098019864019

Byrne, J., Sipe, N., & Searle, G. (2010). Green around the gills? The challenge of density for urban greenspace planning in SEQ. *Australian Planner*, *47*(3), 162–177. https://doi.org/10.1080/07293682.2010.508204

Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., & Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. *Environmental Science & Policy*, *62*, 14–23. https://doi.org/10.1016/J.ENVSCI.2016.01.007

Chen, J., Zhou, C., & Li, F. (2020). Quantifying the green view indicator for assessing urban greening quality: An analysis based on Internet-crawling street view data. *Ecological Indicators*, *113*, 106192. https://doi.org/10.1016/J.ECOLIND.2020.106192

Chen, X., de Vries, S., Assmuth, T., Dick, J., Hermans, T., Hertel, O., … Reis, S. (2019). Research challenges for cultural ecosystem services and public health in (peri-)urban environments. *Science of the Total Environment*, *651*, 2118–2129. https://doi.org/10.1016/j.scitotenv.2018.09.030

Città Metropolitana (n.d.) Statistical data of the resident population, tretrieved from http://inumeridibolognametropolitana.it/dati-statistici/popolazione. Last access 23 December 2020

Colding, J., & Barthel, S. (2013). The potential of "Urban Green Commons" in the resilience building of cities. *Ecological Economics*, *86*, 156–166. https://doi.org/10.1016/j.ecolecon.2012.10.016

Coles, R. W., & Bussey, S. C. (2000). Urban forest landscapes in the UK - Progressing the social agenda. *Landscape and Urban Planning*, *52*(2–3), 181–188. https://doi.org/10.1016/S0169-2046(00)00132-8

Comber, A., Brunsdon, C., & Green, E. (2008). Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. *Landscape and Urban Planning*, *86*(1), 103–114. https://doi.org/10.1016/J.LANDURBPLAN.2008.01.002

Comune di Bologna. (2009). *Regolamento Comunale Del Verde*.

Cortinovis, C., Zulian, G., & Geneletti, D. (2018). Assessing nature-based recreation to support urban green infrastructure planning in Trento (Italy). *Land*, 7(4). https://doi.org/10.3390/land7040112

Daniel, T. C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J. W., Chan, K. M. A., … Von Der Dunk, A. (2012). Contributions of cultural services to the ecosystem services agenda. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(23), 8812–8819. https://doi.org/10.1073/pnas.1114773109

Daniels, B., Zaunbrecher, barbara S., Paas, B., Ottermanns, R., Ziefle, M., & Ross-Nickoll, M. (2018). Assessment of urban green space structures and their quality from a multidimensional perspective. *Science of the Total Environment*, *615*, 1364–1378.

Dempsey, N., Brown, C., & Bramley, G. (2012). The key to sustainable urban development in UK cities? The influence of density on social sustainability. *Progress in Planning*, 77(3), 89–141. https://doi.org/10.1016/j.progress.2012.01.001

Dickinson, D. C., & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. *Ecosystem Services*, *25*, 179–194. https://doi.org/10.1016/j.ecoser.2017.04.014

Edelenbos, J., Molenveld, A., Mojanchevska, K., Ensenado, E., Buddin-Polo Ballinas, M., Esteban, A., … Tsatsou, A. (2020). Community-based initiatives in the urban realm what conditions their performance.pdf. *Journal of Environmental Planning and Management*.

Ekkel, E. D., & de Vries, S. (2017). Nearby green space and human health: Evaluating accessibility metrics. *Landscape and Urban Planning*, *157*, 214–220. https://doi.org/10.1016/j.landurbplan.2016.06.008

Ernstson, H. (2013). The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes. *Landscape and Urban*

Planning, *109*(1), 7–17. https://doi.org/10.1016/j.landurbplan.2012.10.005
Ferreira, V., Barreira, A. P., Loures, L., Antunes, D., & Panagopoulos, T. (2020). Stakeholders' engagement on nature-based solutions: A systematic literature review. *Sustainability (Switzerland)*, *12*(2), 1–27. https://doi.org/10.3390/su12020640
Fischer, A., & Eastwood, A. (2016). Coproduction of ecosystem services as human-nature interactions - An analytical framework. *Land Use Policy*, *52*, 41–50.
Fish, R., Church, A., & Winter, M. (2016). Conceptualising cultural ecosystem services: A novel framework for research and critical engagement. *Ecosystem Services*, *21*(November), 208–217. https://doi.org/10.1016/j.ecoser.2016.09.002
Fondazione Innovazione Urbana (n.d.) Map of Laboratori di Quartiere 2017-2018-2019 available at: https://www.arcgis.com/apps/MapJournal/index.html?appid=4b4cc3819b174c78855e1c0cedb34e65 . Last access 30 December 2020
Francis, J., Wood, L. J., Knuiman, M., & Giles-Corti, B. (2012). Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science and Medicine*, *74*(10), 1570–1577. https://doi.org/10.1016/j.socscimed.2012.01.032
Fu, B., Xu, P., Wang, Y., Guo, Y., Zhang, Y., & Li, S. (2020). Critical areas linking the supply and demand of cultural ecosystem services: Accessibility and geological disasters. *Global Ecology and Conservation*, *21*, e00839. https://doi.org/10.1016/j.gecco.2019.e00839
Fumagalli, N., Fermani, E., Senes, G., Boffi, M., Pola, L., & Inghilleri, P. (2020). Sustainable co-design with older people: The case of a public restorative garden in Milan (Italy). *Sustainability (Switzerland)*, *12*(8), 3166. https://doi.org/10.3390/SU12083166
Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019
Gong, F., Zheng, Z.-C., & Ng, E. (2016). Modeling Elderly Accessibility to Urban Green Space in High Density Cities: A Case Study of Hong Kong. *Procedia Environmental Sciences*, *36*, 90–97. https://doi.org/10.1016/j.proenv.2016.09.018
Grunewald, K., Richter, B., Meinel, G., Herold, H., & Syrbe, R. U. (2017). Proposal of indicators regarding the provision and accessibility of green spaces for assessing the ecosystem service "recreation in the city" in Germany. *International Journal of Biodiversity Science, Ecosystem Services and Management*, *13*(2), 26–39. https://doi.org/10.1080/21513732.2017.1283361
Gupta, K., Roy, A., Luthra, K., Maithani, S., & Mahavir. (2016). GIS based analysis for assessing the accessibility at hierarchical levels of urban green spaces. *Urban Forestry and Urban Greening*, *18*, 198–211. https://doi.org/10.1016/j.ufug.2016.06.005
Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., … Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, *43*(4), 413–433. https://doi.org/10.1007/s13280-014-0504-0
Hamstead, Z. A., Fisher, D., Ilieva, R. T., Wood, S. A., McPhearson, T., & Kremer, P. (2018). Geolocated social media as a rapid indicator of park visitation and equitable park access. *Computers, Environment and Urban Systems*, *72*(February), 38–50. https://doi.org/10.1016/j.compenvurbsys.2018.01.007
Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E., & Pauleit, S. (2019). Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators*, *96*(November 2016), 99–110. https://doi.org/10.1016/j.ecolind.2017.09.042
Hegetschweiler, K. T., de Vries, S., Arnberger, A., Bell, S., Brennan, M., Siter, N., … Hunziker, M. (2017). Linking demand and supply factors in identifying cultural ecosystem services of urban green infrastructures: A review of European studies. *Urban Forestry and Urban Greening*, *21*, 48–

59. https://doi.org/10.1016/j.ufug.2016.11.002
Ibes, D. C. (2015). A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. *Landscape and Urban Planning*, *137*, 122–137. https://doi.org/10.1016/j.landurbplan.2014.12.014
Iperbole (n.d.) Comune di bologna Civic network. Available at: http://partecipa.comune.bologna.it/beni-comuni Last access 30 december 2020
ISTAT - Istituto Italiano di Statistica (2011). Data on resident popultion available at: http://dati.istat.it/Index.aspx?QueryId=42869 last access 30 December 2020
Jennings, V., Larson, L., & Yun, J. (2016). Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. *International Journal of Environmental Research and Public Health*, *13*(2). https://doi.org/10.3390/ijerph13020196
Jerome, G., Sinnett, D., Burgess, S., Calvert, T., & Mortlock, R. (2019). A framework for assessing the quality of green infrastructure in the built environment in the UK. *Urban Forestry and Urban Greening*, *40*(January 2018), 174–182. https://doi.org/10.1016/j.ufug.2019.04.001
Joassart-Marcelli, P., Wolch, J., & Salim, Z. (2011). Building the healthy city: The role of nonprofits in creating active urban parks. *Urban Geography*, *32*(5), 682–711. https://doi.org/10.2747/0272-3638.32.5.682
Kabisch, N., & Haase, D. (2014). Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and Urban Planning*, *122*, 129–139. https://doi.org/10.1016/J.LANDURBPLAN.2013.11.016
Kabisch, N., Strohbach, M., Haase, D., & Kronenberg, J. (2016). Urban green space availability in European cities. *Ecological Indicators*, *70*, 586–596. https://doi.org/10.1016/j.ecolind.2016.02.029
Kabisch, N., & van den Bosch, M. A. (2017). Urban Green Spaces and the Potential for Health Improvement and Environmental Justice in a Changing Climate. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), *Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice* (pp. 207–220). https://doi.org/10.1007/978-3-319-56091-5_12
Kandziora, M., Burkhard, B., & Müller, F. (2013). Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators: A theoretical matrix exercise. *Ecological Indicators*, *28*, 54–78. https://doi.org/10.1016/j.ecolind.2012.09.006
Kaźmierczak, A. (2013). The contribution of local parks to neighbourhood social ties. *Landscape and Urban Planning*, *109*(1), 31–44. https://doi.org/10.1016/j.landurbplan.2012.05.007
Kruszynska, E., & Poczta, J. (2020). Difficulties limiting access to sports and recreational facilities in the city in the perceptions of service users. Sports and Recreational Infrastracture Management policy - Poznan case Study. *International Journal of Environmental Research and Public Health*, *17*.
La Rosa, D. (2014). Accessibility to greenspaces: GIS based indicators for sustainable planning in a dense urban context. *Ecological Indicators*, *42*, 122–134. https://doi.org/10.1016/j.ecolind.2013.11.011
Landry, S. M., & Chakraborty, J. (2009). Street trees and equity: Evaluating the spatial distribution of an urban amenity. *Environment and Planning A*, *41*(11), 2651–2670. https://doi.org/10.1068/a41236
Langemeyer, J., & Connolly, J. J. T. (2020). Weaving notions of justice into urban ecosystem services research and practice. *Environmental Science & Policy*, *109*, 1–14. https://doi.org/10.1016/J.ENVSCI.2020.03.021
Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning. *Risk Management and Healthcare Policy*. https://doi.org/10.2147/RMHP.S61654

Low, S. (2013). Public space and diversity: distributive, procedural and interactional justice
for parks. In: Young, G., Stevenson, D. (Eds.), The Ashgate Research Companion to Planning and Culture. Ashgate, Surrey, pp. 295–310.

Maes, J., Zulian, G., & Thijssen, M. (n.d.). *Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute) Inception report*.

Martins, B., & Nazaré Pereira, A. (2018). Index for evaluation of public parks and gardens proximity based on the mobility network: A case study of Braga, Braganza and Viana do Castelo (Portugal) and Lugo and Pontevedra (Spain). *Urban Forestry and Urban Greening*, *34*(May), 134–140. https://doi.org/10.1016/j.ufug.2018.06.014

McGinlay, J., Parsons, D. J., Morris, J., Graves, A., Hubatova, M., Bradbury, R. B., & Bullock, J. M. (2018). Leisure activities and social factors influence the generation of cultural ecosystem service benefits. *Ecosystem Services*, *31*, 468–480. https://doi.org/10.1016/j.ecoser.2018.03.019

Milcu, A. I., Hanspach, J., Abson, D., & Fischer, J. (2013). Cultural ecosystem services: A literature review and prospects for future research. *Ecology and Society*, *18*(3). https://doi.org/10.5751/ES-05790-180344

Millenium Ecosystem Assessent. (2005). *Ecosystems and Human Well-being: Synthesis.* https://doi.org/10.5822/978-1-61091-484-0_1

Ngom, R., Gosselin, P., Blais, C., & Rochette, L. (2016). Type and proximity of green spaces are important for preventing cardiovascular morbidity and diabetes—a cross-sectional study for Quebec, Canada. *International Journal of Environmental Research and Public Health*, *13*(4). https://doi.org/10.3390/ijerph13040423

Paracchini, M. L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J. P., Termansen, M., … Bidoglio, G. (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. *Ecological Indicators*, *45*(2014), 371–385. https://doi.org/10.1016/j.ecolind.2014.04.018

Peschardt, K. K., Schipperijn, J., & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). *Urban Forestry and Urban Greening*, *11*(3), 235–244. https://doi.org/10.1016/j.ufug.2012.04.002

Pham, T., Apparicio, P., Seguin, A.-M., Landry, S., & Gagnon, M. (2012). Spatial distribution of vegetation in Montreal_ An uneven distribution or environmental inequity.pdf. *Landscape and Urban Planning*, *107*, 212–224.

Plieninger, T., Dijks, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy*, *33*, 118–129. https://doi.org/10.1016/J.LANDUSEPOL.2012.12.013

Pouso, S., Borja, A., Fleming, L.E., Gomez-Baggethun, E., White, M. P., Uyarra, M. C. (2021) Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. *Science of the Total Environment 765.* https://doi.org/10.1016/j.scitotenv.2020.143984

Pröpper, M., & Haupts, F. (2014). The culturality of ecosystem services. Emphasizing process and transformation. *Ecological Economics*, *108*, 28–35. https://doi.org/10.1016/j.ecolecon.2014.09.023

Quatrini, V., Tomao, A., Corona, P., Ferrari, B., Masini, E., & Agrimi, M. (2019). Is new always better than old? Accessibility and usability of the urban green areas of the municipality of Rome. *Urban Forestry and Urban Greening*, *37*(July 2017), 126–134. https://doi.org/10.1016/j.ufug.2018.07.015

Quatrini, V., Tomao, A., Corona, P., Ferrari, B., Masini, E., Agrimi, M., … Ibes, D. C. (2016). GIS based analysis for assessing the accessibility at hierarchical levels of urban green spaces. *Urban Forestry and Urban Greening*, *13*(May), 198–211. https://doi.org/10.2788/279663

Raymond, C. M., Gottwald, S., Kuoppa, J., & Kyttä, M. (2016). Integrating multiple elements of environmental justice into urban blue space planning using public participation geographic information systems. *Landscape and Urban Planning*, *153*, 198–208. https://doi.org/10.1016/j.landurbplan.2016.05.005

Ruiz-Ballesteros, E., & Cáceres-Feria, R. (2016). Community-building and amenity migration in community-based tourism development. An approach from southwest Spain. *Tourism Management*, *54*, 513–523. https://doi.org/10.1016/j.tourman.2016.01.008

Rusche, K., Reimer, M., & Stichmann, R. (2019). Mapping and assessing green infrastructure connectivity in European city regions. *Sustainability (Switzerland)*, *11*(6). https://doi.org/10.3390/SU11061819

Rutt, R. L., & Gulsrud, N. M. (2016). Green justice in the city: A new agenda for urban green space research in Europe. *Urban Forestry & Urban Greening*, *19*, 123–127. https://doi.org/10.1016/J.UFUG.2016.07.004

Satterfield, T., Gregory, R., Klain, S., Roberts, M., & Chan, K. M. (2013). Culture, Intangibles and metrics in environmental management. *Journal of Environmental Management*, *117*, 103–114. https://doi.org/10.1016/j.jenvman.2012.11.033

Schubert, P., Ekelund, N. G. A., Beery, T. H., Wamsler, C., Jönsson, K. I., Roth, A., … Palo, T. (2018). Implementation of the ecosystem services approach in Swedish municipal planning. *Journal of Environmental Policy and Planning*, *20*(3), 298–312. https://doi.org/10.1080/1523908X.2017.1396206

Sievers-glotzbach, S. (2013). Ecosystem Services and Distributive Justice:Considering Access Rights to ecosystem services in theories of distributive justice. *Ethics, Policy &Environment*, *16*(2), 162–176.

Šiljeg, S., Marić, I., Nikolić, G., & Šiljeg, A. (2018). Accessibility analysis of urban green spaces in the settlement of Zadar in Croatia. *Sumarski List*, *142*(9–10), 487–497. https://doi.org/10.31298/sl.142.9-10.4

Subiza-Pérez, M., Hauru, K., Korpela, K., Haapala, A., & Lehvävirta, S. (2019). Perceived Environmental Aesthetic Qualities Scale (PEAQS) – A self-report tool for the evaluation of green-blue spaces. *Urban Forestry and Urban Greening*, *43*(February), 126383. https://doi.org/10.1016/j.ufug.2019.126383

Talen, E. (2003). Neighborhoods as service providers: A methodology for evaluating pedestrian access. *Environment and Planning B: Planning and Design*, *30*(2), 181–200. https://doi.org/10.1068/b12977

Tan, Z., Ka-Lun Lau, K., Roberts, A. C., Tzu-Yuan Chao, S., & Ng, E. (2019). Designing Urban Green Spaces for Older Adults in Asian Cities. *International Journal of Environmental Research and Public Health*, *16*.

Texier, M. Le, Schiel, K., & Caruso, G. (2018). The provision of urban green space and its accessibility: Spatial data effects in Brussels. *PLoS ONE*, *13*(10), 1–17. https://doi.org/10.1371/journal.pone.0204684

Tian, Y., Jim, C. Y., & Wang, H. (2014). Assessing the landscape and ecological quality of urban green spaces in a compact city. *Landscape and Urban Planning*, *121*, 97–108. https://doi.org/10.1016/j.landurbplan.2013.10.001

Tooke, T. R., Klinkenberg, B., & Coops, N. C. (2010). A geographical approach to identifying vegetation-related environmental equity in Canadian cities. *Environment and Planning B: Planning and Design*, *37*(6), 1040–1056. https://doi.org/10.1068/b36044

Tozer, L., Hörschelmann, K., Anguelovski, I., Bulkeley, H., & Lazova, Y. (2020). Whose city? Whose nature? Towards inclusive nature-based solution governance. *Cities*, *107*(August), 102892. https://doi.org/10.1016/j.cities.2020.102892 van Berkel, D. B., & Verburg, P. H. (2014). Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. *Ecological Indicators*, *37*, 163–174. https://doi.org/10.1016/j.ecolind.2012.06.025

Van Herzele, A., & Wiedemann, T. (2003). A monitoring tool for the provision of accessible and attractive urban green spaces. *Landscape and Urban Planning*, *63*(2), 109–126. https://doi.org/10.1016/S0169-2046(02)00192-5

Vasiljevic, N., & Gavrilovic, S. (2019). Cultural Ecosystem Services. *Springer Nature Switzerland AG 2019. W. Leal Filho et Al. (Eds.), Life on Land, Encyclopedia of the UN Sustainable Development Goals,* 209–218. https://doi.org/10.1007/978-3-319-95981-8_47

Wallace, K. J. (2007, October 1). Classification of ecosystem services: Problems and solutions. *Biological Conservation*, Vol. 139, pp. 235–246. https://doi.org/10.1016/j.biocon.2007.07.015

Wen, C., Albert, C., & Von Haaren, C. (2020). Equality in access to urban green spaces: A case study in Hannover, Germany, with a focus on the elderly population. *Urban Forestry and Urban Greening*, *55*(August), 126820. https://doi.org/10.1016/j.ufug.2020.126820

WHO. (2016). *Urban green spaces and health. Copenhagen: WHO Regional office for Europe*.

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities "just green enough." *Landscape and Urban Planning*, *125*, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017

Wolch, J., Wilson, J. P., & Fehrenbach, J. (2005). Parks and park funding in los angeles: An equity-mapping analysis. *Urban Geography*, *26*(1), 4–35. https://doi.org/10.2747/0272-3638.26.1.4

Wüstemann, H., Kalisch, D., & Kolbe, J. (2017). Access to urban green space and environmental inequalities in Germany. *Landscape and Urban Planning*, *164*(September 2016), 124–131. https://doi.org/10.1016/j.landurbplan.2017.04.002

Ye, C., Hu, L., & Li, M. (2018). Urban green space accessibility changes in a high-density city: A case study of Macau from 2010 to 2015. *Journal of Transport Geography*, *66*(November 2017), 106–115. https://doi.org/10.1016/j.jtrangeo.2017.11.009

Zulian, G., Paracchini, M.L., Maes, J., Liquete C. (2013). ESTIMAP: Ecosystem services mapping at European scale. Joint Research Centre . Institute for Environment and Sustainability. Luxembourg: Publications Office of the European Union.

7 PLANNING THE FUTURE AROUND ECOSYSTEM SERVICES: THE CASE OF BARCELONA

ABSTRACT

While most studies are working on the mapping and assessing current ES in urban GBI and UGAs, only a few discuss the impacts of possible external drivers of change, e.g. land use change, increase of human pressure, climate change of inherent drivers of change, e.g. demographic social or economic changes within the urban socio-ecological system (SES). As presented in Chapter 4, the need for building urban resilience has increasingly gained attention in the last decade both in science, and in practice, and it has received substantial policy interest. Tailored and adaptive policies and interventions need to reduce resilience of the barriers to equitable access and distribution of ES benefits and to build and increase resilience around the factors that enable the flow of ES benefits over time. However, from a practical perspective, while mathematical modelling and machine learning approach can support predictions of plausible future, building resilience around urban SES is far from obvious. The aim of this chapter is to give a step forwards into ES-based planning, looking at their own resilience through the time and guiding cities towards desired and sustainable futures, where ES supply matches ES demands. More specifically, we will build on the presented aspects (see Chapter 4) of resilience, *of what? to what?,* and *for whom*? to help navigating ES resilience-oriented policymaking. To this aim, within this Chapter we will present a transdisciplinary and mixed-method research approach to address urban ES resilience and its implementation in the City of Barcelona. Results of the implementation of the proposed approach in the city of Barcelona will be presented and discussed at the end of this Chapter[4].

[4] An adapted version of this Chapter has been accepted for publication in Ecology and Society. De Luca, C., J. Langemeyer, S. Vaňo, F. Baró and E. Andersson. Adaptive resilience of and through urban ecosystem services: A trans-disciplinary approach to sustainability in Barcelona. (2021)

7.1 CASE STUDY: THE CITY OF BARCELONA

With 1.62 million inhabitants in an area of 101.35 km^2, Barcelona is the second largest city in Spain and one of the most compact and densely populated cities in Europe with about 16,000 inhabitants km^{-2} (Barcelona City Council Statistical Yearbook 2019). In the last years, the Barcelona City Council has embraced an ES-based approach in urban greening policy, developing several strategies and plans to support the city trajectory towards a more sustainable future, such as the Barcelona Green Infrastructure and Biodiversity Plan 2020 (Ajuntament de Barcelona, 2014), Guide to Living Terrace Roofs and Green Roofs (Ajuntament de Barcelona 2015), the Trees for Life : Master Plan for Barcelona's Trees 2017 – 2037 (Ajuntament de Barcelona 2017), and the Climate Action Plan, '*Pla Clima 2018-2030*' (Ajuntament de Barcelona, 2018c). The latter identifies greening and the related provision of urban ES as one of the most important measures to be applied against climate change. It also sets the goal to increase urban green space by 1.6 km2 (equivalent to one additional square meter per inhabitant,) which would correspond to an overall increase of 15% in the city's urban green areas. In the context of this thesis, we decided to use Barcelona as case study to explore ES resilience due to i) its recognized role as a frontrunner city in ES-based planning and ii) at the same time of the writing, Barcelona City Council is working on the development of urban resilience strategy (Ajuntament de Barcelona, 2018a) through the coordinated work of several City Departments including the recently established City's Urban Resilience Department.

This study is then embedded in a current discourse of resilience building, with the intention to assess urban ES resilience and explore new policy options to secure and unlock the flow of those benefits in the future. The study builds upon a workshop co-organized by the author during her visiting stay at the Institute of Science and Technology for the environment of the Universitat Autonoma de Barcelona (ICTA-UAB), as part of an ongoing stakeholder engagement process taking place in Barcelona since 2013 (in the context of the European research projects FP7-Openness, BiodivERsA3-ENABLE, EC-H2020-NATURVATION, and EC-ERC-URBAG).

7.2 METHODS TO ASSESS AND FURTHER ENHANCE RESILIENCE THINKING AROUND ES

The study adopted a transdisciplinary and mixed-method research approach (Díaz-Reviriego et al., 2019) of sequential methodological steps to address urban ES resilience. First, we develop the Urban Ecosystem Services Resilience Assessment Matrix to perform a systematic analysis of how municipal sustainability policies aligned with ES resilience principles (Section 8.2.1) (following Biggs et al. 2012 under consideration of Borgström et al. 2015, Nykvist et al. 2017, Andersson et al. 2019). Second, we co-created four scenario narratives to investigate potential external drivers or inherent changes of Socio Ecological System (SES) (Nelson et al., 2005) (Section 8.2.2). The themes for the scenarios were defined through multiple iterations with the City's Urban Resilience Department of Barcelona. Third, we present the modalities to build a participatory approach around ES resilience to trigger critical thinking about possible future shifts in supply and demand of ES (Section 8.2.3). This new understanding was finally used to prompt expert-stakeholders to reflect on the adaptation required for a transition to more desirable futures and to propose targeted policy interventions.

7.2.1 POLICY ANALYSIS - ES RESILIENCE ASSESSMENT INTO CURRENT GBI RELATED URBAN POLICIES

Within this study, we propose to limit the policy analysis to policies developed at city level, dealing with sustainability, climate and greening and potentially affecting, directly or indirectly, urban GBI. The procedure followed a two-step approach: the first step included a screening of all the 10 policies identified with a two-fold objective: i) to translate the resilience principles into a context relevant articulation that could inform an understanding of resilience of what and to what; and ii) to verify and assess the relevance and scope of the selected policies relative to the ES resilience framework. Consistent with (Geneletti & Zardo, 2016; Rozas-Vásquez, Fürst, Geneletti, & Almendra, 2018), our policy screening did not employ a strict keyword-based content analysis, but relied on both explicit and non-explicit qualitative content analysis applied to all sustainability related policies of the city. Neither ES nor the resilience terminologies are yet standardized, and both will always be contingent with regard to the context and must be sensitive to alternative languages (Camps-Calvet, Langemeyer, Calvet-Mir, & Gómez-Baggethun, 2016; Meerow, Newell, & Stults, 2016; Sellberg, Wilkinson, & Peterson, 2018). Thus, in the first screening step we translated the generic resilience principles identified by (Biggs et al., 2012) to a case relevant set of variables described in a language that resonated with how the policies were formulated. In addition to this first step, we then performed the full analysis through the developed Urban Ecosystem Services Resilience Assessment Matrix (Table 1). This matrix builds on Biggs et al. 2012; Borgström et al. 2015; Nykvist, Borgström, and Boyd 2017, and aims at adapting ES resilience thinking principles to the urban realm. Assessment variables spanned the realms of socio-cultural diversity, urban morphology, planning approaches and normative context, consideration of external drivers (tourism, climate change, housing, technological innovation, demographic and political change) and inherent changes (human preferences and lifestyle) in the urban SES, as detailed in Table 7-1. We translated qualitative judgments (high, medium and low) on the level of incorporation of resilience principles into each policy using a score from 1 (low incorporation) to 5 (high incorporation) to facilitate the representation of the results. The connections between the variables and the seven resilience principles are detailed in Annex II.

Table 7-1 Urban ecosystem services resilience assessment matrix (based on Biggs et al., 2012; Borgström et al. 2015, and Nykvist et al. 2017)

ES Resilience Principle addressed	Aspects addressed	Guiding questions for the assessment
P1, P4	**Diversity consideration**	*Biological diversity:* How are genetic, species and landscape level diversity addressed? How are interactions between species and/or ecological succession addressed? How is complementarity in the landscape addressed? *Social diversity:* How are the different socio-economic components of the urban areas analysed? How are cultural and historical values considered? *Structural diversity:* How is urban structure (in terms of neighbourhoods' differences and components) considered? Spatial/temporal scale is considered?
P1, P5, P6	**Use of different knowledge spheres**	What kind of knowledge is used? How is involvement of different stakeholders in planning, design, management, monitoring etc. addressed? Spatial/temporal scale is considered?
P2	**Physical connectivity**	How is green and blue infrastructure (structures, nodes, networks, species migration etc.) addressed? How is mobility and physical accessibility addressed? How is information flow addressed? Spatial/temporal scale is considered?
P3, P4	**Disturbance regimes**	What disturbances are recognized? What responses are addressed (coping, adapting, transforming)?
P3, P4	**Assessment of forecast, possible changes and uncertainty**	What changes are recognised, e.g. climate, demographical, economic, political, technological innovation, human preferences and lifestyle (CES), tourism, housing, land use planning? Are changes in relation with future supply and demand of ES considered and addressed? How are monitoring, evaluation and revision addressed? Spatial/temporal scale is considered?
P3, P4, P5	**System knowledge approach**	How are the management steps of monitoring, evaluating, revising and adapting addressed? How are emergent signals captured? How are responses to changes addressed?
P3, P4, P5	**Institutional flexibility**	In what ways is the approaches to GBI reactive or proactive? How are alternative approaches recognized? What kind of formulations are used, e.g. shall, should, recommend?

7.2.2 CO-DESIGN OF SCENARIO NARRATIVES

We propose to design the expert-stakeholder workshop in close collaboration with the City's Urban Resilience Department, if any, or with the Planning and Greening Departments. This process include the development of scenario narratives, describing plausible futures affecting future urban social-ecological systems configuration (Palomo, Martín-López, López-Santiago, & Montes, 2011; Priess & Hauck, 2014). The co-development of scenario narratives particularly serves to identify and highlight critical external drivers of change and inherent system changes with potential negative impacts on ES flows, e.g. mismatches of ES capacity and demand (Baró et al., 2016; Villamagna et al., 2013). Also, in this phase, the most relevant ecosystem for the urban future will be selected. For the case of Barcelona, this selection of ES, which was adapted through discussions with the Urban Resilience Department built on results from a preceding workshop with local stakeholders that had focussed on the prioritization urban land-uses for the local production of ES (Langemeyer et al. 2020). If possible, it would be preferable to build on previous works and cooperation already established in the city. The following ES were deemed relevant for purposes of this study: (a) regulation of microclimate, (b) runoff control, (c) air purification, (d) carbon sequestration, (e) noise reduction, (f) social cohesion, (g) physical recreation, (h) mental wellbeing, and (i) tourism recreation.

7.2.3 BUILDING AND ASSESSING THE PARTICIPATORY WORKSHOP

The workshop should start with a general introduction on the topic of GBI and ES, tailoring this to the overall knowledge of the participants. After a general introduction, workshop organizers will present the results of the policy analysis performed through the Urban Ecosystem Services Resilience Assessment Matrix (UESRAM). After this first general part where participants get familiar with the Es resilience principles and their current integration into city's policies, participants will be divided into four distinct and heterogeneous break-out groups to work on two main exercises:

(1) simulation of shifting ES capacity and demand;

(2) development of policy options to build resilience around ES.

Each of the four groups will be assigned to work with one specific scenario narrative, which situate the discussion on shifting ES capacity and demand. Within each future scenario, participants will be asked to assess potential (no)changes in ES, based on combination of the following factors: (1) increase/decrease number of users and relative awareness of benefits leading to higher/lower pressure on urban GBI – shift in ES demand; (2) increase/decrease in availability of urban GBI leading to lower/higher ES capacity. In the analysis of the results, a numerical valued can be given to determine whether the assessed demand for and capacity of the single ES in a given scenario would: decrease substantially (-2), decrease moderately (-1), stay unchanged (0), increase moderately (+1) or increase substantially (+2). In presenting the results we use average values, while interpreting varieties in responses might have served to account for lacking consensus over changes in capacity and demand of ES and as an indicator for uncertainty.

Based on the results of the ES capacity and demand assessment in the different scenarios, participants will be asked to propose tailored and adaptive policy interventions to build resilience around ES flows tackling the specific issues raising form the different scenarios. In the context of this study, the policies and interventions proposed have been clustered into different policy sectors together with the workshop participants and proposed policy measures were further analysed by the authors after the workshop. For each policy option proposed, the analysis identified which systemic filters (infrastructure, institutions and perceptions, Andersson et al. 2019, 2020) were primarily addressed, as well as which type of resilience principles were incorporated using the Urban Ecosystem Services Resilience Assessment Matrix presented in Table 8.1. This process allowed to assess whether the applied resilience thinking approach was reflected in the policy measures proposed. Specific modalities of each workshop session are further detailed in Annex VI and Annex VII.

7.3 ECOSYSTEM SERVICES RESILIENCE RESULTS

7.3.1 INTEGRATION OF ES RESILIENCE PRINCIPLES INTO CURRENT BARCELONA POLICY

Ten GBI related policies were screened and coded based on their alignment with and treatment of urban ES and their relevant resilience aspects (Annex III).

Six policies have been considered highly relevant ES resilience thinking. Nevertheless, two planning documents, i.e. the new Metropolitan Master Plan and the Superblock programme have not been assessed with the developed matrix. Indeed, the new Master Plan was under development and not available at the time of the analysis, and the Superblock programme contains a series of diagnosis and guidelines for re-designing Barcelona neighbourhoods and streets, developing action-oriented guidelines that were not considered relevant for this study. Four policies were analysed more in depth based on the *Urban Ecosystem Services Resilience Assessment Matrix* (Table 7-1) namely (a) the Barcelona

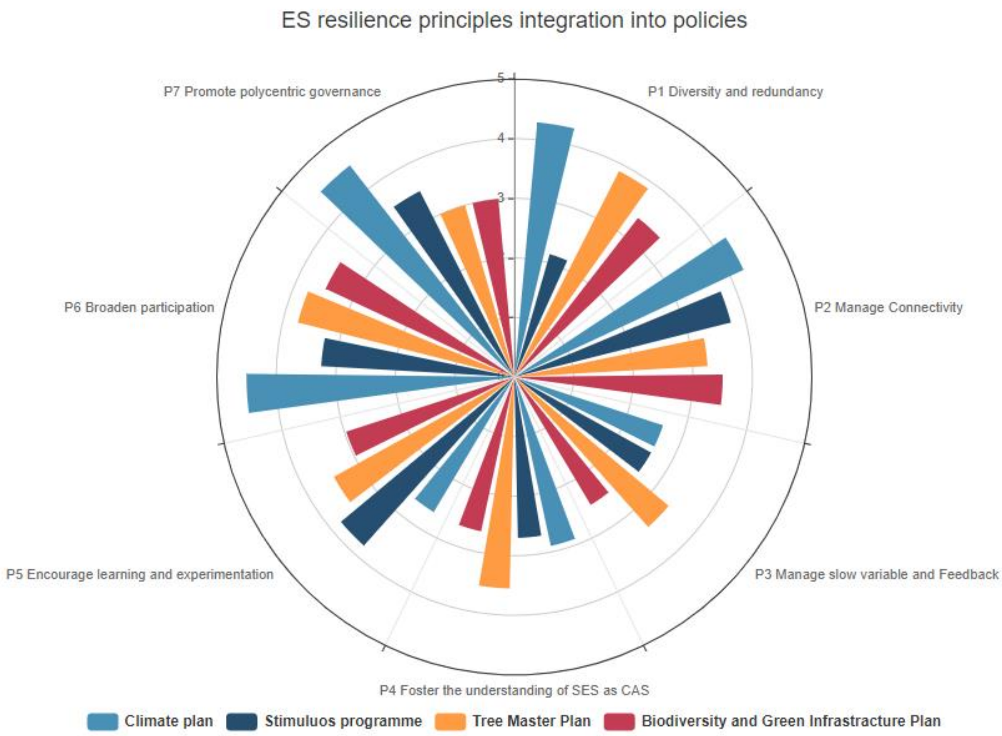


Figure 7-1 Results of the Policy assessment using the Urban Ecosystem Services Resilience Assessment Matrix . incorporation of resilience principles into each policy uses a score from 1 (low incorporation) to 5 (high incorporation)

Biodiversity and Green Infrastructure Plan 2020 (BGIP) (Ajuntament de Barcelona, 2013), together with (b) the Stimulus programme for the city's urban green infrastructure (SP) (Ajuntament de Barcelona, 2017), (c) the Tree Master Plan 2017-2037 (TMP) (Ajuntament de Barcelona., 2017) and (d) the Climate Plan 2018-2030 (CP) (Ajuntament de Barcelona, 2018b). The policy screening revealed a general recognition of GBI as a source of ES provision and as an important asset for Barcelona's resilience strategy, particularly reflected in the city's greening and climate policies. In line with previous studies (Cortinovis and Geneletti 2018; De Luca et al. 2021), these urban policies primarily refer to regulating and cultural ES. Furthermore, the policies incorporated, to some extent, resilience principles that would help sustaining ES in the future.

Fig. 7-1 summarizes the degree of integration and consideration of the seven principles of ES resilience - (P1) to maintain diversity and redundancy, (P2) to manage connectivity, (P3) to manage slow variables and feedbacks, (P4) to foster an understanding of complex adaptive systems, (P5) to encourage learning and experimentation, (P6) to broaden participation, and (P7) to promote polycentric governance systems- in four core policies. Particularly the structural role of GBI in the city is well acknowledged (P1, P2), both in terms of their current state as well as future actions to improve them, mostly related with the *infrastructure* filter. For instance, biological diversity and redundancy (P1) have been specifically accounted in terms of biodiversity preservation in the Biodiversity and Green Infrastructure Plan, in the Stimulus Programme and in the Tree Master Plan. However, structural and socio-economic diversity (P1) of the urban area is not addressed, except for the Climate Plan, which considered some socio-economic issues together with demographic variables (P1, P4). These include inherent changes such as possible increase of population, migration, and external drivers as climate change impact on vulnerable neighbourhoods and population groups. The Climate Plan also refers to other relevant policies and plans, clearly showing links, connections, synergies and opportunities with other policy sectors (P3, P4). None of the three other plans (The Biodiversity and Green Infrastructure Plan, the Stimulus Programme and the Tree Master Plan) accounts for possible shifts in future ES demands, thus widely neglecting the *perceptions* filter, at least in face of systemic changes. Furthermore, the policy analysis indicates an explicit but one-dimensional focus on adaptation to climate change, while the management of other slow variables and feedbacks (P3) as well as a broader understanding of the city as complex adaptive system (P4) is generally lacking. Greening strategies do recognize major disturbances caused by plagues and climate-related events, but do not consider other possible changes and disturbances (P3, P4), for example related to growing and shifting ES demands or capacities.

7.3.2 SCENARIOS OF CHANGE AFFECTING ECOSYSTEM SERVICE RESILIENCE

After multiple iterations with the Urban Resilience Department, four scenarios were proposed as most relevant drivers of change to Barcelona's ES flows: (I) aging and shrinking population, (II) enhanced tourism, (III) gender inequalities, and (IV) global warming (Fig 7-2). The four scenarios and the results of the policy analysis constituted the entry points for triggering participants' thoughts on possible disturbances and changes on capacity and demand sides of critical ES in the future. Participants were asked to assess and discuss the changes in capacity and demand for each ES to explore the potential gap between the growing demand for and recessing capacity of given ES (Fig. 7-2). For the detailed description of resulted scenario see Annex V.

Scenario #1 Aging and shrinking

There is an outmigration of young population and ageing of resident population. The pressures on health, mobility, housing, job availability, and social services have substantially increased. Resulting side-effects are reflected in depression and loneliness of elderly, lacking opportunities to engage (socially or economically), and in public health and wellbeing. City is lacking accessible open green spaces, as these have capacity to provide manifold social and environmental benefits.

Scenario #2 Enhanced tourism

Mass tourism is a source of wealth but also of complex challenges. The pressures on housing, services, and urban space availability as well as on urban environment have substantially increased. Rising prices, increase in illegal activities, overcrowded and degraded open spaces, changing attitudes of residents living in affected central neighbourhoods. Affected residents are deprived of available green spaces and beaches for recreation. Several local movements have emerged and started to act.

Scenario #3 Gender inequalities

An increasing number of women is reporting negative experiences from their visits of open spaces, also due to misperception and disinformation. Public spaces are dominantly used by male population due to changes in users' perception. Equal access to green and open public spaces is questioned. The access to green spaces by women became limited, as they perceive them as unsafe. Female population is deprived of benefits related with urban nature.

Scenario #4 Global Warming

Climate change has intensified and is affecting the city and its residents. Increase in the number of torrid days, droughts, fires, rain-shortages, and water scarcity represent and immense challenge for the future life in the city. Some residents are affected more than other; especially vulnerable groups are elderly, children, and pregnant woman. Similarly, heavily build-up areas are affected the most. An increased importance of friendly and climate-resilient open spaces is highlighted.

Figure 7-2 Four scenario narratives co-developed with the Urban Resilience Department. Each scenario is centred around a single narrative that represent major challenge for urban sustainability

7.3.3 SHIFTING ECOSYSTEM SERVICES DEMAND AND CAPACITY

Across the four break-out groups working on the different scenarios, during the workshop participants generally assessed that the ES demand will remain stable or increase while the capacity of ES is supposed to stay unchanged or to decrease. More specifically, our study reveals that *mental wellbeing*, followed by *regulation of microclimate*, *social cohesion*, *air purification*, *physical recreation*, and *runoff control and soil permeability* are the most susceptible ES to future changes, indicated by the capacity-demand gaps in Fig.7-3. On the other hand, *noise reduction*, *tourism recreation* and *carbon sequestration* appear to be relatively stable in terms of their capacity and demand.

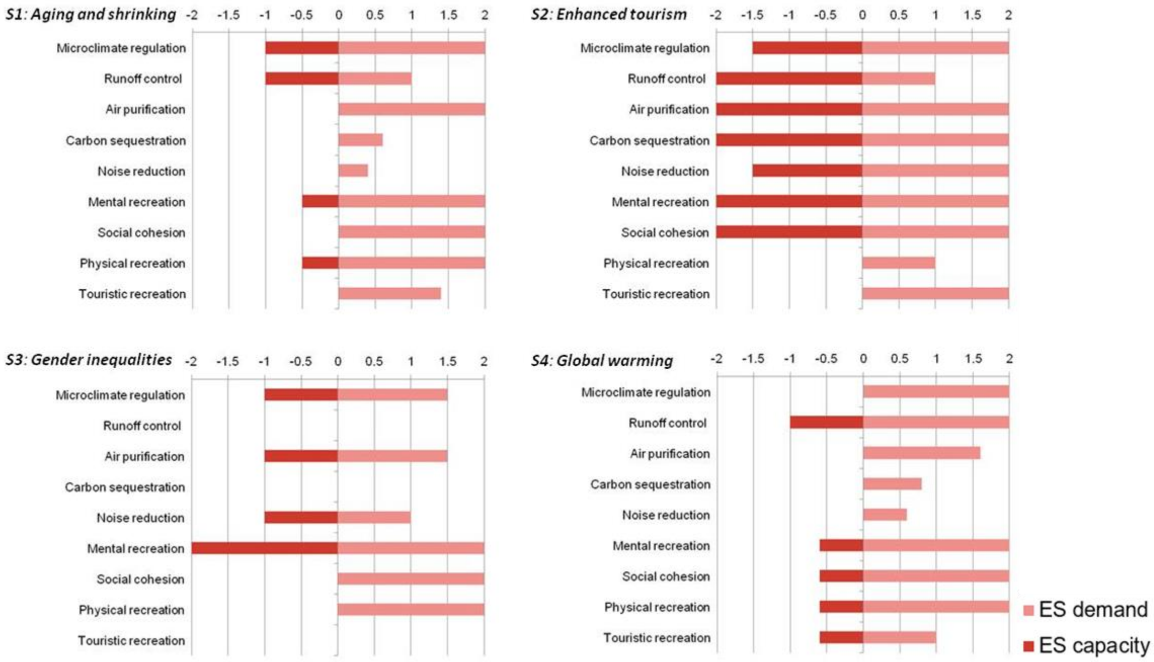


Figure 7-3 Shifting ES capacity and demand in 4 scenarios. The negative numeric values refer to decreasing ES capacity while the positive numeric values refer to increasing ES demand.

Seemingly the smallest mismatches between capacity and demand applies to *tourism recreation*. However, participants agreed that mass tourism and related demands for *tourism recreation* generated by GBI will have impact on availability of and accessibility to green spaces. This in turn negatively impacts the provision of other GBI related benefits, including *mental and physical recreation* and *social cohesion* which all are derived from GBI through direct nature experiences (Bratman et al. 2019) and which appear to be more vulnerable to changes (Fig. 7-3). Given the complexity of the resilience thinking exercise, consensus was difficult to reach in some cases, especially in the supply evaluation side. In global warming scenario, the group had diverging views on changes in supply of regulatory services and they made consensus on 'no changes' only after assuming that the Barcelona's elaborated strategies, including Climate Plan, Green Infrastructure and Biodiversity Plan, or Tree Master Plan, have potential to improve ES capacity. In gender equality scenario, the group did not reach a consensus over changes in supply of social and relational benefits and recreational opportunities. Some considered that supply would increase simply because women would be excluded from daily use of the public space, while others opposed this idea. In enhanced tourism, some considered the supply of recreational opportunities and of tourism and economic benefits will increase only in the core urban areas due to new development and emerged economic opportunities, while will decrease in the city's outskirts.

7.3.4 ADAPTIVE POLICIES TO MAINTAIN ES POTENTIALS

To match an overall increased demand and uncertain supply of ES, the policy measures proposed by participants can be summarized in two larger clusters. First, measures aiming at increasing and sustaining current GBI infrastructures and the related capacity to generate regulating ES and cultural ES over time. Second, measures that would improve access to GBI for city inhabitants through a more inclusive and participatory design and that would mitigate pressure on GBI, primarily through the limitation of the number of visitors, especially tourists. Figure 7-4 summarizes linkages between the identified policy clusters, the Enable filters (Andersson et al. 2019), the Resilience principles (Biggs et al. 2012) and capacity and demand of Cultural (CES) and Regulating (RES) Ecosystem Services. Thicker lines represent stronger relationships between them and provide insights of the enabling impact of diverse policy options on ES resilient capacity and demand.

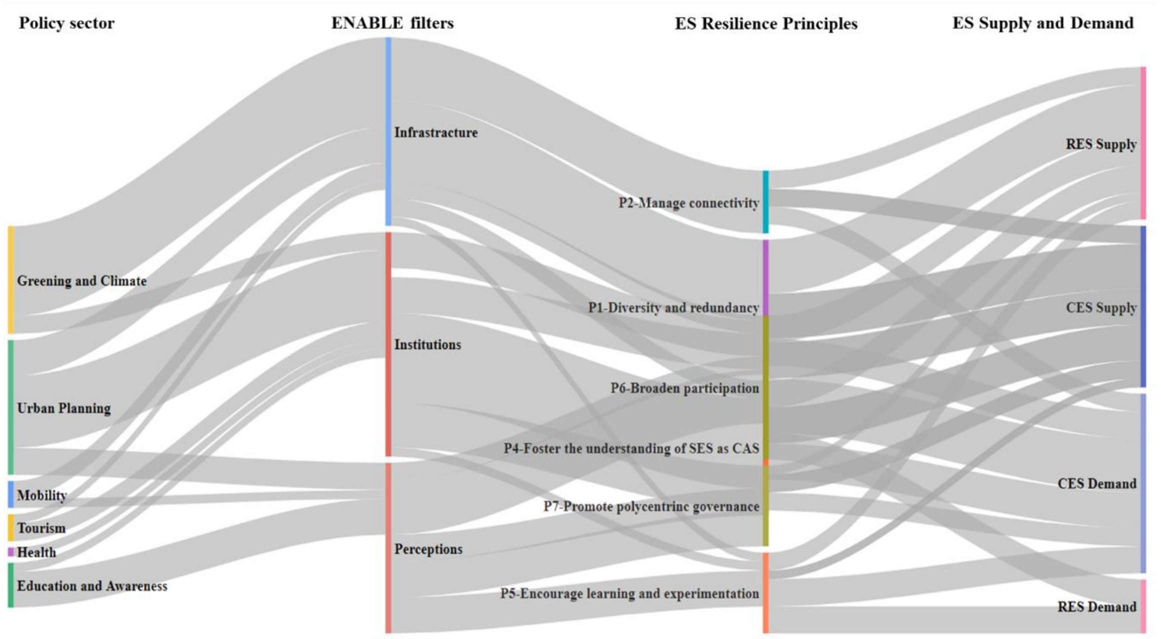


Figure 7-4 Linkages between the identified policy clusters, the Enable filters (Andersson et al. 2019) the Resilience principles (Biggs et al. 2012) and capacity and demand of Cultural (CES) and Regulating (RES) Ecosystem Services.

Infrastructure

Most of the greening measures proposed during the workshop include direct interventions on the current structure of the GBI in the city, i.e. to expand it, improve its quality and to make it more interconnected. As shown in Figure 4, greening and climate measures were understood as promoting diversity and redundancy as well as increasing the extent of GBI: suggested actions range from creating new green areas, developing sustainable urban drainage system (SUDS) and permeable surfaces, to increasing vegetation and biodiversity, improving nodes and connectivity among different green areas. Thus, the strategies taken promote both the diversity (P1) of GBI and its connectivity (P2), two central aspects of resilience. Interestingly, several policy measures addressed transport and mobility (part of the grey *infrastructure*) as a sector that strongly affects the availability or the lack of GBI benefits (*cf.* Biernacka and Kronenberg 2019). The measures suggested here captured the user side of ES generation, and primarily by addressing connectivity (P2). Suggestions focused on improved connectivity, redesigning sustainable and slow mobility to leave space to green areas, and better integrating GBI and grey infrastructure, but also raised the importance of rethinking the role of the airport in the city, reflecting on limitations to its expansion.

Institutions

Many of the policy interventions discussed target GBI by addressing processes of maintenance and management rather than GBI directly; for instance, involving citizens in urban transformation processes and projects to boost community care and maintenance of the GBI, as well as the promotion of relational and healthy aspects such as, for example, the management of urban gardens. Urban planning is one of the guiding instruments at the core of *institutions* (Andersson et al. 2019), and many measures refer to land-use rights, actor roles, responsibilities, and the different ways people can be involved in changing how land is planned and used. Measures related to institutions and governance processes covered a diverse range of options, from the proposal of including technological innovations and greening criteria as requirement in building codes, mostly acting on regulating and cultural ES capacity and influencing (P1) and (P2), but also increasing accessibility, inclusivity and security to existing green areas (ES demand). Participants also proposed measures that frame the ways people can be involved in changing how land is perceived and used addressing GBI co-design through the active participation of vulnerable groups (P6), elderly and women explicitly mentioned in the respective scenarios, and include community initiatives for the improvement and the maintenance of the local GBI (P1, P6), including fostering civic stewardship of GBI (in line with Andersson et al. 2019; Langemeyer et al. 2018). Diverse measures regard tourism and the need of better managing touristic flows not to overcrowd urban green areas and to limit cultural ES demand in specific places of the city and its surroundings. Proposals addressing tourism also included financial adjustments with the idea of partly redirecting tourism taxes in greening protection, maintenance and improvement, opening for possibilities of learning from landscape and parks management outside the city (i.e. Laarman and Gregersen, 1996 and Eagles, 2014). Measures proposed also touched upon the relation of greening and health, considering the idea of including access to green in the annual health report, as the potential benefits of accessing green on human health of the city and managing slow variables and feedback (P3).

Perceptions

At the same time, looking at beneficiaries and taking into account that GBI benefits are co-produced and the individual potential to realize ES benefits is closely interrelated and shaped by the cultural and institutional context (Andersson et al., 2019), participants addressed *perceptions* in several measures, slightly differently in the scenarios proposed. For example, urban farming was mainly addressed in the ageing scenario, and recognized as one of the main enablers of GBI benefits for elderly (confirming previous results by Camps-Calvet et al., 2016), while stronger attention has been dedicated to boost security (P1, P4), improved accessibility (P1, P2) and more inclusive co-design, co-management and co-maintenance (P5, P6, P7) in the gender inequalities scenario. The feeling of insecurity and the unjust distribution of ES benefits among different citizens groups were at the core of this discussion (in line with Maruthaveeran and van den Bosch 2014). Education (learning) and awareness raising measures (P5) were raised as critical for involving different target groups (elderly, children, women, students) and mostly refer to environmental education activities that would improve the understanding of urban ES flows and benefits in the face of diverging ES demands and perceptions (see Riechers, Barkmann, and Tscharntke 2016). This included a proposal for developing mechanisms to support value creation and recognition of, for example, public soil and the ES capacity (P4) to support and improve guidelines for local land use decision-making.

7.4 ECOSYSTEM SERVICES RESILIENCE DISCUSSION

7.4.1 APPLICATION OF THE URBAN ECOSYSTEM SERVICES RESILIENCE ASSESSMENT MATRIX

The application of the Urban Ecosystem Services Resilience Assessment Matrix to the sustainability policies of the city of Barcelona revealed an overall satisfactory understanding of Principle 1 and 2 to improve condition, accessibility, and connectivity of the urban GBI, well-embedding the biological and landscape diversity in the measures proposed and considering to a certain extent also the social and the structural diversity of the urban GBI. A good uptake of Principle 6 and Principle 7 is revealed, acknowledging the raising interest of the City of Barcelona of actively engaging citizens and stakeholders in the decision-making processes, well-defining responsibilities, tools and collaboration methods. Also, scientific and technical knowledge of urban ES and GBI (Principle 5) is well integrated into all the policies analysed, which constitutes an ideal entry point for science-driven approaches to fill the existing gaps in current policies. Nevertheless, even though the analysed policies included monitoring and possible adaptation schemes to some extent, none of them has defined a clear approach to identify emergent signals, disturbances, or unforeseen changes, nor potential responses to those (Principle 3, Principle 4). As already stated by McPhearson et al. 2015b, urban ES are particularly valued in the context of climate adaptation, improved citizens' health and wellbeing, and as means of enhancing city's resilience (resilience through urban ES). In contrast, resilience of urban ES in changing conditions, i.e. possible variables, disturbances, slow feedback and changes, has not been adequately considered yet. While climate change scenarios and their possible impacts over current GBIs, human health and wellbeing are considered within current policies, a broader resilience thinking approach would be needed to tackle other potential external (i.e pandemic, technological innovation) or inherent (demographic, lifestyle changes, housing and socio-economic) drivers of change. The added value of applying the developed Urban Ecosystem Services Resilience Assessment Matrix (Table 1) consisted in the possibility of considering not just the policy impact on the ecological component of resilience of the urban GBI, but also the social interactions that the urban GBI is subject to, thus reflecting in the analysis the complexity of cities as adaptive socio-ecological systems.

7.4.2 SCENARIO DEVELOPMENT AND ES MISMATCHES IDENTIFIED – RESILIENCE TO WHAT, OF WHAT, FOR WHOM?

Departing from the identified gaps through the policy assessment and to foster answers around our three main research questions (*resilience of what, to what and for whom?*), the complexity of Barcelona as adaptive socio-ecological system was reflected through the development of four scenarios to be presented to the workshop participants. The scenario co-development exercise at the interface between science and policy represents itself a step to further resilience thinking (Pereira, Sitas, Ravera, Jimenez-Aceituno, & Merrie, 2019). Throughout the workshop, after getting familiar with the different future scenarios (*resilience to what?*), participants generally found it easier to start with the evaluation of ES demands. Especially demand for cultural ES (i.e. citizen's needs) were assigned the highest importance, and were the focus of most discussions, thereby providing complementarity to the vast majority of urban ES studies focussing on (changing) ES supply (Haase et al., 2014). Indeed, a diversity of beneficiaries' *perceptions* (i.e. elderly, residents and tourists, and women) and possible evolution of vulnerable groups' demand over the time have been explored by workshop participants. Equal access and inclusively designed green spaces have been considered crucial to address shifting ES demand in the future (e.g. Fumagalli et al. 2020). Shifting ES demands and beneficiaries' *perceptions* were not very prominent in the analysed policies (3.1), suggesting that the co-development and use in the workshop of the scenario on aging, gender and tourism strongly supported resilience thinking towards this specific point (*resilience for whom?*). Even though instructed to work with a single scenario, participants often considered different drivers – especially mass tourism and global warming – at the same time, which indicates a general potential in applying expert-stakeholder workshops in order to examine wicked problems of complex interacting external and inherent changes in relation to multiple ES demands that are generally difficult to get hold of by other approaches (e.g. mathematical modelling) (Pereira et al. 2019, Galafassi et al. 2018). Also, on the *perception* filter, the use of the scenario narrative strongly supported participants in better understanding potential changing needs of different groups of GBI users, thus facilitating the understanding of current and future ES demand. Scenario narratives thus supported not just stakeholders' understanding of the consequences of possible development paths (*resilience of what and to what?*) (Dahlhaus, Weißkopf, Dahlhaus, & Weißkopf, 2017), but it also contributed to develop an inclusive vision for future sustainability (*resilience for whom?*) and to propose concrete policy adaptation to achieve it (Palomo et al., 2011).

7.4.3 TRANS-DISCIPLINARY RESILIENCE BUILDING ADAPTIVE POLICY MEASURES PROPOSED

In short, the policy measures proposed during the workshop considerably overlap with actions and ideas already included in current policies of the cities, not least in the Climate Plan (Ajuntament de Barcelona, 2018b). However, in general, they were much broader than the limited number of policies which already refer to ES resilience, as identified through our policy analysis.

Measures emerged touching upon the infrastructure filter embrace the understanding of the interconnected role of Gray and Green infrastructure in the city. This measure mostly emerged from the enhanced tourism scenario and intends to mitigate the rising ES demand, fostering the understanding of the complexity of the urban system (P4), manifested in global teleconnections of ES (Seto et al., 2012). Limiting both airport and port (cruise ships) traffic would not only decrease cultural ES demand and thus the pressure on the current GBI, but also reduce air pollution and greenhouse gas emissions, thus decreasing the need for urban GBI to provide these ES. The green and blue infrastructure and its different ecological qualities provide the first necessary precondition for ES (Andersson et al., 2019), including their maintenance and resilience over time. In addition to making the structure of the GBI more resilient, the highly human modified urban ecosystems are dependent on management and long-term governance to maintain or, in many cases, strengthen their qualities. Interestingly in this vein, Amorim Maia et al. 2020 had found in a recent study for Barcelona that especially aesthetically less pleasing green spaces (without monuments, fountains etc.) — i.e. a lower quality regarding common GBI indicators — could have a more inclusive character and foster social inclusion, while mitigating social segregation. When asked to develop policy adaptations based on the identified ES shifts in supply and demands, participants often develop measures touching upon policy sectors such as mobility, tourism, and health. While it is broadly recognized that urban planning decisions in sectors such as land use (Li et al., 2018; Tan et al., 2020), and transport and mobility (Ghent, 2018), and tourism (Taff, Benfield, Miller, D'antonio, & Schwartz, 2019) have a strong impact over the ES capacity over the time, the workshop results suggested that these changes can also largely affect ES demand. Also while the impact of ES on humans health and wellbeing are at the centre of many studies, measures also suggested to better look at long-term observation of health benefits, and the capacity of GBI to fulfil this need on the other. The discussion triggered by the scenarios clearly showed that, on the institutional side, policy sectors beyond urban greening and planning, e.g. health, tourism, transport and mobility, education and awareness, need to be included in decision-making about land-use and quality of life. This points to the role of collaboration to foster the understanding of urban areas as complex socio-ecological and adaptive systems (P4), through enhanced cross-scale approaches. It thus resulted that the role of institutions in enabling GBI benefits flow is not limited to urban planning, land use policies and building rights, but extends to other actors and policy sectors that become co-responsible enablers or inhibiter of GBI benefits in the city. Decisions made in sectors such as tourism, transport and mobility, health, and education and awareness can heavily influence ES flows in cities and enable or hamper their resilience over time. Implicitly, by recognising these linkages and using them to track performance over time, the broad suite of measures all related to the same theme (ES) offer more opportunities to also manage slow variables and detect critical thresholds in the system (P3).

7.5 CONCLUSIONS AND FUTURE DIRECTIONS

Our study provides a stepwise and transdisciplinary approach to engage with urban policy-making in order to foster adaptive resilience of and through urban ecosystem services. The approach consisted in understanding the cities trajectory, developing possible future scenarios in order to assess vulnerabilities and to co-develop pathways to enhance adaptive capacities from an inclusive perspective. There the application of the *Urban Ecosystem Services Resilience Assessment Matrix* integrating Bigg's resilience principles and Andersson's three filters approach showed useful results in the case study application. It allowed highlighting the need for adaptive policies not only to focus on re-shaping *infrastructures*, but to address *institutions* and *perceptions* alike. Acting preventively by anticipating future needs and *perceptions* and developing new modes of decision-making, co-creation and co-management of GBI would support the sustainability and resilience of ES over the time. Applying and adapting Biggs et al.'s seven principles to the urban realm and connected them with the three filters, we argue that adaptive policies (as an *institutional* tool) should shape not just current *infrastructures*, while speaking to and reframing the actual *perceptions* of beneficiaries, but should also act preventively, anticipating future needs and *perceptions*. In this direction, the application of the *Urban Ecosystem Services Resilience Assessment Matrix* into policies and planning and the implementation of a participatory approach using scenario narrative, can work as a lens for understanding city trajectory over sustainability and resilience, identifying leverage points into current policy framework for unlocking the flows of ES from nature to humans (*resilience of what*), dealing with uncertainties (*resilience to what*) and ensuring inclusiveness for all (*resilience for whom*).

The study revealed for the City of Barcelona an explicit need for fostering systemic, iterative resilience thinking, considering multi-layered processes of change and different feedback loops. It further recognized the requirement to strengthen awareness and to advance learning among key urban stakeholders and planners about urban social-ecological systems as complex adaptive systems. Other ES resilience principles (Biggs et al., 2012), including diversity and redundancy, the management of connectivity encouraging learning, education, participation, and polycentric governance were already stronger anchored both in the policies and stakeholders' mindsets. Furthermore, the study indicates specific dimensions of ES supply and demand to be especially vulnerable to change, for instance microclimate regulation, water balances, mental wellbeing and social cohesion. Thereby it indicates where the cities current trajectory is not pointing towards sustainability goals, and highlights the specific objectives for action in order to initiate an abrupt transformation (cf. Elmqvist et al. 2019).

The stakeholder platform previously established in the City of Barcelona strongly supported this process, given the high awareness and previously generated knowledge on the topic. Nevertheless, the involvement of expert stakeholders coming from other policy fields, with different knowledge on the GBI and ES topics and expertise in sectors other than sustainability and resilience, would be beneficial to further explore, investigate and boost the role of institutions collaboration and fostering the understanding of urban area as complex socio-ecological and adaptive system (P4). Indeed, it clearly comes out from our study that boosting cooperation, improving inter-departmental collaboration and integrating cross-sectorial policy is crucial to enable and raise the recognition of the role of GBI and to unlock related benefit flows in the city. A stronger consideration of ES in other policy fields is thus demanded and the application of the Urban Ecosystem Services Resilience Assessment Matrix to analyse the impacts of policies from other sectors (e.g. housing, transport, health, etc.) to the urban GBI, could also be explored in this light. Also, the proposed scenarios triggered reflections over uncertainty in planning, creating debate, and not always consensus, on future shifts in ES supply and demand over the time. This uncertainty could bring to the consideration of alternative and flexible approaches (Principle 4) (Walker et al., 2001) based on constant monitoring, evaluation, and revision, that are mentioned, but not fully addressed in current policies.

Ajuntament de Barcelona. (2017). Trees for life : Master Plan for Barcelona's Trees 2017 - 2037. *Àrea d'Ecologia Urbanisme i Mobilitat*.

Ajuntament de Barcelona. Àrea d'Ecologia Urbanisme i Mobilitat. (2015). *Guide to living terrace roofs and green roofs*.

Ajuntament de Barcelona. (2013). *Barcelona Green Infrastructure and biodiversity plan 2020*.

Ajuntament de Barcelona. (2014). *Plan del Verde y de la Biodiversidad de Barcelona 2020*.

Ajuntament de Barcelona. (2017). Stimulus programme for the city's urban green infrastructure : Government measure. *Comissió d'Ecologia, Urbanisme i Mobilitat (Consell Municipal de Barcelona) Àrea d'Ecologia, Urbanisme i Mobilitat*.

Ajuntament de Barcelona. (2018a). *Barcelona : preliminary resilience assessment* (p. Gerència d'Ecologia (Associació), 100 Resilient Ci). p. Gerència d'Ecologia (Associació), 100 Resilient Ci.

Ajuntament de Barcelona. (2018b). *Climate Plan 2018-2030*.

Ajuntament de Barcelona. (2018c). *Pla Clima 2018-2030*.

Amorim Maia, A. T., Calcagni, F., Connolly, J. J. T., Anguelovski, I., & Langemeyer, J. (2020). Hidden drivers of social injustice: uncovering unequal cultural ecosystem services behind green gentrification. *Environmental Science and Policy*, *112*(July), 254–263. https://doi.org/10.1016/j.envsci.2020.05.021

Andersson, E., Langemeyer, J., Borgström, S., McPhearson, T., Haase, D., Kronenberg, J., … Baró, F. (2019). Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems. *BioScience*, *69*(7), 566–574. https://doi.org/10.1093/biosci/biz058

Baró, F., Palomo, I., Zulian, G., Vizcaino, P., Haase, D., & Gómez-Baggethun, E. (2016). Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region. *Land Use Policy*, *57*, 405–417. https://doi.org/10.1016/J.LANDUSEPOL.2016.06.006

Biernacka, M., & Kronenberg, J. (2019). Urban Green Space Availability, Accessibility and Attractiveness, and the Delivery of Ecosystem Services. *Cities and the Environment (CATE)*, *12*(1).

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S. B., Cundill, G., … West, P. (2012). Toward Principles for Enhancing the Resilience of Ecosystem Services. *Ssrn*. https://doi.org/10.1146/annurev-environ-051211-123836

Borgström, S., Bodin, Ö., Sandström, A., & Crona, B. (2015). Developing an analytical framework for assessing progress toward ecosystem-based management. *Ambio*, *44*, 357–369. https://doi.org/10.1007/s13280-015-0655-7

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., … Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances*, *5*(7). https://doi.org/10.1126/sciadv.aax0903

Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., & Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. *Environmental Science & Policy*, *62*, 14–23. https://doi.org/10.1016/J.ENVSCI.2016.01.007

Cortinovis, C., & Geneletti, D. (2018). Ecosystem services in urban plans: What is there, and what is still needed for better decisions. *Land Use Policy*, *70*, 298–312. https://doi.org/10.1016/j.landusepol.2017.10.017

Dahlhaus, N., Weißkopf, D., Dahlhaus, N., & Weißkopf, D. (2017). *Future Scenarios of Global Cooperation—Practices and Challenges (Global Dialogues 14).*

De Luca, C., Tondelli, S., Martin, J., (2021). Ecosystem Services Integration into Local Policies and Strategies in the City of Bologna: Analysis of the State of the Art and Recommendations for Future Development. DOI:10.1007/978-3-030-54345-7. pp.127-139. In Ecosystem Services and Green Infrastructure Perspectives from Spatial Planning in Italy edited by Arcidiacono, A. e Ronchi S.

Díaz-Reviriego, I., Turnhout, E., & Beck, S. (2019). Participation and inclusiveness in the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services. *Nature Sustainability*, *2*(6), 457–464. https://doi.org/10.1038/s41893-019-0290-6

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., … Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability*, *2*(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Frantzeskaki, N. (2019). Seven lessons for planning nature-based solutions in cities. *Environmental Science and Policy*, *93*(December 2018), 101–111. https://doi.org/10.1016/j.envsci.2018.12.033

Fumagalli, N., Fermani, E., Senes, G., Boffi, M., Pola, L., & Inghilleri, P. (2020). Sustainable co-design with older people: The case of a public restorative garden in Milan (Italy). *Sustainability (Switzerland)*, *12*(8), 3166. https://doi.org/10.3390/SU12083166

Galafassi, D., T. M. Daw, M. Thyresson, S. Rosendo, T. Chaigneau, S. Bandeira, L. Munyi, I. Gabrielsson, and K. Brown. (2018). Stories in social-ecological knowledge cocreation. Ecology and Society 23(1):23. https://doi.org/10.5751/ES-09932-230123

Geneletti, D., & Zardo, L. (2016). Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy*, *50*, 38–47. https://doi.org/10.1016/J.LANDUSEPOL.2015.09.003

Ghent, C. (2018). Mitigating the Effects of Transport Infrastructure Development on Ecosystems. *Consilience: The Journal of Sustainable Development*, *18*(1), 58–68.

Jansson, Å. (2013). Reaching for a sustainable, Resilient urban future using the lens of ecosystem services. *Ecological Economics*, Vol. 86, pp. 285–291. https://doi.org/10.1016/j.ecolecon.2012.06.013

Langemeyer, J., & Connolly, J. J. T. (2020). Weaving notions of justice into urban ecosystem services research and practice. *Environmental Science & Policy*, *109*, 1–14. https://doi.org/10.1016/J.ENVSCI.2020.03.021

Langemeyer, J., Wedgwood, D., McPhearson, T., Baró, F., Madsen, A. L., & Barton, D. N. (2020). Creating urban green infrastructure where it is needed – A spatial ecosystem service-based decision analysis of green roofs in Barcelona. *Science of the Total Environment*, *707*, 135487. https://doi.org/10.1016/j.scitotenv.2019.135487

Li, Z., Cheng, X., Han, H., Palomo, I., Martín-López, B., López-Santiago, C., … Wiese, F. (2018). How urban densification influences ecosystem services - A comparison between a temperate and a tropical city. *Ecology and Society*, *17*(1), 1–17. https://doi.org/10.1111/1365-2664.12550

Maruthaveeran, S., & van den Bosch, C. C. K. (2014). A socio-ecological exploration of fear of crime in urban green spaces - A systematic review. *Urban Forestry and Urban Greening*, *13*(1), 1–18. https://doi.org/10.1016/j.ufug.2013.11.006

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015a). Resilience of and through urban ecosystem services. *Ecosystem Services*, *12*, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015b). Resilience of and through urban ecosystem services. *Ecosystem Services*, *12*, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. *Landscape and Urban Planning*, *147*, 38–49. https://doi.org/10.1016/J.LANDURBPLAN.2015.11.011

Nelson, G. C., Bennett, E., Berhe, A. A., Cassman, K. G., Defries, R., Dietz, T., … Zurek, M. (2005). Drivers of change in ecosystem condition and services. *Ecosystems and Human Well-Being; Scenarios. Millenium Ecosystem Assessment* , *2*, 173–222.

Nykvist, B., Borgström, S., & Boyd, E. (2017). Assessing the adaptive capacity of multi-level water governance: ecosystem services under climate change in Mälardalen region, Sweden. *Regional Environmental Change*, *17*(8), 2359–2371. https://doi.org/10.1007/s10113-017-1149-x

Palomo, I., Martín-López, B., López-Santiago, C., & Montes, C. (2011). Participatory scenario planning for protected areas management under the ecosystem services framework: The Doñana social-ecological system in Southwestern Spain. *Ecology and Society*, *16*(1). https://doi.org/10.5751/ES-03862-160123

Pereira, L., Sitas, N., Ravera, F., Jimenez-Aceituno, A., & Merrie, A. (2019). Building capacities for transformative change towards sustainability: Imagination in Intergovernmental Science-Policy Scenario Processes. *Elementa: Science of the Anthropocene*, 7. https://doi.org/10.1525/elementa.374

Priess, J. A., & Hauck, J. (2014). Integrative scenario development. *Ecology and Society*, *19*(1). https://doi.org/10.5751/ES-06168-190112

Riechers, M., Barkmann, J., & Tscharntke, T. (2016). Perceptions of cultural ecosystem services from urban green. *Ecosystem Services*, *17*, 33–39. https://doi.org/10.1016/j.ecoser.2015.11.007

Rozas-Vásquez, D., Fürst, C., Geneletti, D., & Almendra, O. (2018). Integration of ecosystem services in strategic environmental assessment across spatial planning scales. *Land Use Policy*, *71*, 303–310. https://doi.org/10.1016/j.landusepol.2017.12.015

Sellberg, M. M., Wilkinson, C., & Peterson, G. D. (2018). *Resilience assessment : a useful approach to navigate urban sustainability*. *20*(1).

Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., … Simon, D. (2012). Urban land teleconnections and sustainability. *Proceedings of the National Academy of Sciences*, *109*(20), 7687–7692. https://doi.org/10.1073/PNAS.1117622109

Taff, B. D., Benfield, J., Miller, Z. D., D’antonio, A., & Schwartz, F. (2019). The role of tourism impacts on cultural ecosystem services. *Environments - MDPI*, *6*(4), 1–12. https://doi.org/10.3390/environments6040043

Tan, P. Y., Zhang, J., Masoudi, M., Alemu, J. B., Edwards, P. J., Grêt-Regamey, A., … Wong, L.

W. (2020). A conceptual framework to untangle the concept of urban ecosystem services. *Landscape and Urban Planning*, Vol. 200. https://doi.org/10.1016/j.landurbplan.2020.103837

Unt, A. L., & Bell, S. (2014). The impact of small-scale design interventions on the behaviour patterns of the users of an urban wasteland. *Urban Forestry and Urban Greening*, *13*(1), 121–135. https://doi.org/10.1016/j.ufug.2013.10.008

Villamagna, A. M., Angermeier, P. L., & Bennett, E. M. (2013). Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. *Ecological Complexity*, *15*, 114–121. https://doi.org/10.1016/j.ecocom.2013.07.004

Walker, W. E., Rahman, S. A., & Cave, J. (2001). Adaptive policies, policy analysis, and policy-making. *European Journal of Operational Research*, *128*(2), 282–289. https://doi.org/10.1016/S0377-2217(00)00071-0

8 CONCLUSIONS AND FUTURE RESEARCH

8.1 INTRODUCTION

Ecosystem services (ES) provided by nature and urban ecosystems offer multiple benefits necessary to cope with present and future urban challenges (Gascon et al., 2015; Gómez-Baggethun & Barton, 2013). Long-term urban policies and strategies can play a central role in maintaining and increasing ES toward more sustainable, liveable and resilient cities, but their integration and operationalization into urban planning processes is still lacking.

Evolving conceptual frameworks for urban ecology view cities as heterogeneous, dynamic landscapes and as complex, adaptive, socio-ecological systems, in which the delivery of ecosystem services links society and ecosystems at multiple scales (Grimm et al., 2008). One of the most interesting interpretation for understanding these complex links is the Ecosystem Services cascade model (Haines-Young and Potschin, 2010), that both includes the analysis of the capacity of the ecological system to provide benefits (ES supply),and looks at the social system through the analysis of the demand that request, making use and valuing ecosystem services and related benefits.

The overall aim of this research has been to better understand the role of GBI, NBS and ES towards urban sustainability and resilience at international and European, for providing interpretative and operational methods at urban level. Through the analysis of current international (Chapter 2) and European (Chapter 3) normative framework, we emphasized the contribution of nature and cities in reaching the defined targets towards sustainability, climate mitigation and adaptation, biodiversity and sustainable resource management, highlighting possible gaps and areas where further integration would boost a faster transition and adoption of NBS.

On the other side, we have analysed the complexity of the urban system from a socio-ecological point of view, proposing an adaptation of the ES cascade model (Chapter 4), including the three ENABLE filters (Andersson et al., 2019) and the seven principle of ES resilience (Biggs et al., 2012), and proposing, based on this conceptual framework, methods, tools and participatory approach (Chapter 5,6,7) to plan, improve and manage current and future urban ecosystem and related services. The methods proposed developed on the so-called 'supply-demand' and 'ES resilience' gap (Elmqvist et al. 2013)(McPhearson, Andersson, Elmqvist, & Frantzeskaki, 2015) and have been tested in the cities of Bologna and Barcelona. Specifically, we focused on three Regulating Ecosystem Services (Chapter 5), i.e water retention, PM10 removal and carbon sequestration, through the development of a spatial ES-based model able to prioritize city areas and type of intervention, based on resulting ES supply and demand mismatches. Four diverse areas have been identified in the city of Bologna, according to the main mismatches presented, and specific interventions have been proposed that vary from the implementation of hybrid NBS (green and cool roof, Sustainable Urban Drainage System, green walls, etc.) to wider urban regeneration intervention. In terms of Cultural Ecosystem Services (CES), Chapter 6 further expanded on current research gaps (Dickinson & Hobbs, 2017; Hegetschweiler et al., 2017; La Rosa, Spyra, & Inostroza, 2016) developing methods to assess the overall supply of CES including the quantity (accessibility analysis) and the quality of Urban Green Areas (UGAs) through the development of the Urban Recreational Potential index. The methods have been developed considering four CES – physical recreation, cultural recreation, cognitive development and social relations and cohesion. Specifically, the potential influence of Green Stewards and sport features quality has been assessed, developing on the idea of ES co-production and Urban Green Commons (Colding & Barthel, 2013; Fischer & Eastwood, 2016), using the city of Bologna as case study. The main research findings support the idea that compact dense cities, with limited available space to further expand current GBI, should invest on improving UGAs quality or developing new small and dispersed high-quality UGAs. By developing new governance and funding mechanisms to support Green Stewards and further involving vulnerable groups in the development of the desired sport features, local authorities can largely boost the co-production of ES, enabling the flows of benefits provided by the existing GBI. Last, to further contribute to the discussion on urban environmental justice (Rutt & Gulsrud, 2016), we have assessed the distributional justice of ES benefits in the city, including people vulnerabilities in the spatial analysis. While in the city of Bologna the results did not allow to appreciate a relation between UGAs quantity and population vulnerability, we found a weak, but statistically relevant, negative corelation between UGAs quality and population vulnerability. Since higher vulnerable areas of the city host lower quality UGAs, we assume that this can hamper the flow of ES benefits (mostly related with health and wellbeing) and would contribute to exacerbate existing inequalities among population.

After having developed and tested methods and approaches to map and assess current ES flow within the urban environment, we pointed to the future resilience and sustainability of such Ecosystem

Services (McPhearson et al., 2015). Chapter 7 developed a transdisciplinary approach to assess and enhance sustainability and resilience around ES. Tailoring Biggs's principle to the urban realm, we developed a mixed-method approach (desk research and participatory workshop) to investigate the presence of resilience thinking in the city's greening and sustainability policies. The results of the application of this method in the city of Barcelona fostered the discussion around GBI and ES resilience, addressing the need of intersectoral policy integration (including housing, education and mobility) and fostering a wider understanding of the *institutions*' role. Through the use of scenario narratives, and highlighting the potential of co-creation, the proposed approach enhances critical thought around ES resilience among key players in the city.

The following sections present the conclusions and recommendations drawn from this research. Sections 9.2 presents the conclusions of each research question analysed separately. Section 9.3 discusses data availability and provides suggestions to overcome the gaps. Recommendations for future research are presented in Section 9.3

8.2 FINDINGS ADDRESSING THE RESEARCH QUESTIONS

1. **What does it mean introducing nature in the city? What are the main concepts that have been used in these areas and which are the most relevant for sustainable urban planning?**

Building on current literature summarized in Chapter 4, we acknowledge that currently the most relevant concepts for urban planning are Ecosystem Services (ES), Green and Blue Infrastructures (GBI) and Nature-based Solutions (NBS). Although ES, GBI, and NBS share similar roots, we argue that even if they can all be considered conceptual and operational approaches within urban planning, they assume different roles within the urban transition processes. Within this work, the ES framework is considered as a methodological framework to assess nature's benefits and to inform policy and decision makers on such benefits' distribution, flows, mismatches and shortage, if any. ES supply and capacity assessment offer core information over ecosystems' condition and health, degraded ecosystems, and are useful information to plan their design, management, and resilience over the time. On the other side, ES flows and demand evaluation provides useful information on citizens' behaviour and preferences understanding their perceptions. According to already mentioned studies and literature (Almenar et al., 2021; Nesshöver et al., 2017; Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017) the term GBI has been used to define the overall network of existing urban green areas, elements, and features, coinciding with the ecological system that can provide ES (ES supply). Within this work, we then differentiated urban GBI and Urban Green Areas (UGAs), considering the last as the public, accessible share of the urban GBI. UGAs have been considered as the reference urban GBI for what concern mapping and assessment of Cultural Ecosystem Services (CES), since, to be generated, they need human-nature interaction. The aesthetic relevance of non-accessible GBI has not been considered, as aesthetic service was not among the selected CES for this analysis. On the other side, while many authors considered NBS as an umbrella concepts under which all the other related terms can be related with, we referred to NBS as new urban green areas, elements, and features that might include innovative planning, governance, financial, technological and participatory framework and that should be planned and designed as multifunctional solutions to challenges identified based on socio-ecological evaluation of ES capacity, flows and demand according to the analysis of the existing urban GBIs.

2. To what extent current international and European policies are relevant for and recognized the role of nature and cities? Which gaps currently exist and how can they be addressed?

The history of international agreements on climate, biodiversity and sustainable development, shows that, since the early 70s, the United Nations recognized the need to intervene to modify current unsustainable trajectories, acknowledging the role of humans in natural resources depletion and pollution. The role of cities as major actors of sustainable transition has been clearly recognized since 2015, dedicating to urban sustainable development and transition the SDG n. 11, and dedicating a specific target (11.3) *to providing universal access to safe, inclusive, accessible, and green public spaces by 2030, especially for the most vulnerable groups (women, children, the elderly, and disabled people)*. Also, the New Urban Agenda represents a well-advanced strategic document, that not only recognises the need of renaturing and greening cities to develop towards urban sustainability and just and inclusive societies, but it also acknowledges the role of urban and territorial planning as a crucial instrument in this transition. Also, the New Urban Agenda well reflects the latest scientific research and recognizes the crucial role of urban green spaces because of their multifunctionality, inviting local authorities to consider and evaluate the multiple benefits and co-benefits they provide. Despite the recognized limitation of some of the international agreements, we do acknowledge their potential in boosting a sustainable urban transition. Nevertheless, nowadays, the main question would be whether the attention on climate, biodiversity and sustainable development issues will be shifted for the next years, overshadowed by current health and economic crisis. In this direction, the European Union is gradually moving the sustainability issue at the centre of its own development and growth policy. Evidence and awareness of the potential of natural ecosystems, green infrastructure, and nature-based solutions to support progress towards urban sustainability and its recognition into European Strategies and Directives continue to grow. Since urban planning is not directly under the responsibility or the European Council, NBS and related concepts such as ecosystem-based adaptation, green infrastructure, and natural water retention measures are being increasingly integrated in a range of environmental, climate and biodiversity policies at EU level. Most of these policies have a direct impact on cities, that should either comply with them or integrate those recommendations into their local policies, strategies, and plans. For ES and NBS to be more effectively considered into the Strategic Environmental Assessment, the Flood Directive and the Directive looking at coastal ecosystem, it needs to be ensured that practitioners and policy makers that apply such directives are sufficiently supported in terms of ES and NBS definition, good practices availability and integration processes (Honrado et al., 2013). In this line, the development of specific indicators that support the assessment of co-benefits provided by alternative nature-based approaches and solutions could largely favour such approaches against traditional plans and solutions.

The lately released new EU Green Deal is a crucial step of the EU recovery plan and represents a first step towards the new growth that should transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy (EU Commission, 2019). Including NBS and ES approaches and recognizing the crucial role of urban areas towards sustainable and inclusive growth, has thus to be considered crucial to ensure not only a competitive economy, but also an inclusive and sustainable transition of the EU, maintaining and enhancing European citizens health, wellbeing and quality of life.

3. How to support a comprehensive integration of ES, GBI and NBS into urban planning tools and related policies?

Within this dissertation we proposed a conceptual framework integrating the ES cascade models with the three concepts coming from Andersson et al. 2019 that could support a wider understanding of the relevance of policy making into the system, and the seven principle of ES resilience (Biggs et al., 2012). We then elaborated on the supply-demand gap concerning RES and CES mapping and assessment in the city of Bologna, and on the resilience gap implementing a resilience thinking participatory process in the city of Barcelona. The proposed methods and indicators used in the city of Bologna allowed to perform a comprehensive mapping of hotspots of ES mismatches within the city, evaluating GBI potential deficit in supplying ES and assessing ES demands through an analysis of the needs and vulnerability of the local population. This ES-based planning approach could support urban planning decision making processes according to ecological, climatic, and social criteria, providing adequate indicators and assessment strategies able to reflect the multifaceted functions of the urban GBI. The presented approach goes beyond the traditional quantitative standard approach, providing methods, indicators, and procedures to assess:

- Regulating ES. To better support urban planning and to develop ES-based decision-making process able to prioritize areas and type of intervention, it is crucial to spatially identify which areas present higher mismatches in ES supply and demand, or to spatially assess the flow of the benefits from different areas of the city. Within this work, we managed to highlight spatial mismatches regarding water retention, PM_{10} and carbon sequestration and we proposed following tailored NBS interventions to mitigate the identified mismatches. Up to now, decision-making in UGAs management is mostly based on cost and aesthetic considerations and less on ecological or climatic criteria; through the proposed approach, we believe that building on climatic and ecologic criteria would strongly support business opportunities, knowledge transfer and nature-based innovation for climate adaptation and mitigation technologies. The possibility to define priority areas of intervention could support local authorities to justify the request of higher performance indicators in certain areas of the city, and to provide incentives for encouraging the uptake of innovative solutions. For instance, area-tailored performance threshold (i.e the volume of water that should be retained in a specific re-development area) or planning standard can be included within the local building code, largely improving not only the overall ES supply in terms of water retention, but also enhancing business opportunities for high-efficient nature-based or hybrid innovation technologies.
- Cultural Ecosystem Services (CES). Creating a balance between urban development and availability of UGAs is an environmental challenge which impacts on the quality of life of the inhabitants and on the economic performance of cities (Kabisch and Haase, 2014). Within this work, we proposed methods and indicators to evaluate qualitative and functional aspects of UGAs, including justice principle within a distributional analysis of CES. Assessing CES qualitatively provides deeper understanding on meanings and intricate interactions of inhabitants and their natural surroundings, helping policy and decision-makers to understand

or prevent political conflicts and to acknowledge trade-offs in policy appraisals. It can also contribute to foster public participation and raise awareness (Maraja, Barkmann, & Tscharntke, 2016). The development of the Urban Recreation Potential Index (URPI) attempted to enhance our knowledge around quality of UGAs, building on the idea of ES co-production paths (Andersson, Tengö, McPhearson, & Kremer, 2015; Fischer & Eastwood, 2016). Mapping sport features quality and Urban Green Stewards should be intended as a way of going beyond the mere quantitative overview of the UGAs in the area, even if still needed and crucial, and provides some indications around urban regeneration processes. Indeed, through the application of the URPI index, we argue that UGAs quality is not strictly size-dependent (Peschardt, Schipperijn, & Stigsdotter, 2012) and that urban regeneration processes in compact-dense cities with low possibilities of developing new UGAs should look mainly at the quality of UGAs. This could involve dedicated funding and governance models (i.e. for activating underused UGAs through Green Stewards) (Andersson, Enqvist, & Tengö, 2017; Colding & Barthel, 2013; Webster, 2007) or participated co-design processes (sport features quality) (Fumagalli et al., 2020; Kabisch, van den Bosch, & Lafortezza, 2017). Cultural Ecosystem Services related indicators and assessment methods would then largely contribute to defining not just priority areas of interventions, but also potential social, governance and financial related innovations and could play a crucial role in the development of the plan for the sustainable future of our cities. Last, CES can also expand on the development of just future cities, developing on the idea of distributional access of ES related benefits. While this is also the case for the distribution of RES, (Baró, Calderón-Argelich, Langemeyer, & Connolly, 2019) within this work we focused the attention on the distributional access to CES, relating population vulnerability with UGAs accessibility and UGAs quality. In this regard, results do not show any relation between population vulnerability and UGAs quantity but suggest that higher vulnerable areas of the city host lower quality UGAs. We acknowledge that while meeting the expectations of all social groups in the city is hardly possible, the main priority should be given to satisfying the needs of the most vulnerable inhabitants (Raymond, Gottwald, Kuoppa, & Kyttä, 2016), thus a careful planning to enhance UGAs quality in highly vulnerable areas should be sought, regulating speculation mechanisms that could support gentrification process in such areas.

As acknowledge by the complexity of the models proposed ES mapping and assessment procedures, we believe that ES-based planning requests a widely multidisciplinary approach (Pereira et al. 2019, Maynard et al. 2011). Aiming at further enhancing sustainability, resilience and justice in urban areas and integrate and ES-based approach in urban planning and policies, we recognize the need of a multidisciplinary approach (e.g. ecologist, planners, sociologist, engineers, economist and data analyst among others) to further assess ecological processes and functions of the GBI, and to better include social and economic needs and changing demands among citizens. Also, considering UGAs multifunctionality as an approach to appraise the multiple benefits of urban green spaces would foster synergies between the optimal provision of different functions in compact cities (Hansen 2019). While in our work we treated separately RES and CES, it is crucial to take in mind that the various social, ecological and economic benefits provided by ES and by the proposed NBS to the identified challenges would enhance multifunctionality on all spatial levels, and deliberately arranging climatic, environmental, social and economic functions across space and time (Hansen, Olafsson, van der Jagt, Rall, & Pauleit, 2019).

4. How to ensure Ecosystem Services resilience over the time?

Within this work, we developed a stepwise and transdisciplinary approach to engage with urban policymaking in order to foster adaptive resilience of and through urban ecosystem services. The approach consisted in understanding the cities trajectory, developing possible future scenarios in order to assess vulnerabilities and to co-develop pathways to enhance adaptive capacities from an inclusive perspective. The application of the *Urban Ecosystem Services Resilience Assessment Matrix,* integrating Bigg's resilience principles and Andersson's three filters approach, showed useful results in the case study application. Applying and adapting Biggs et al. 2012 seven principles to the urban realm and connecting them with the three filters (Andersson et al., 2019), we argue that adaptive policies (as an *institutional* tool) should shape not only current *infrastructures*, while speaking to and reframing the actual *perceptions* of beneficiaries, but should also act preventively, anticipating future needs and *perceptions*. In this direction, the application of the *Urban Ecosystem Services Resilience Assessment Matrix* into urban policies and planning and the implementation of a participatory approach using scenario narrative, can work as a lens for understanding the city's trajectory over sustainability and resilience, identifying leverage points into current policy framework for unlocking the flows of ES from nature to humans (*resilience of what*), dealing with uncertainties (*resilience to what*) and ensuring inclusiveness for all (*resilience for whom*). The study revealed for the City of Barcelona an explicit need for fostering systemic, iterative resilience thinking, considering multi-layered processes of change and different feedback loops. It further recognized the requirement to strengthen awareness and to advance learning among key urban stakeholders and planners about urban social-ecological systems as complex adaptive systems. Furthermore, the study indicates specific dimensions of ES supply and demand that are especially vulnerable to change, for instance microclimate regulation, water balances, mental wellbeing and social cohesion. Thereby, it indicates where the cities' current trajectory is not pointing towards sustainability goals, and highlights the specific objectives for action in order to initiate an abrupt transformation (cf. Elmqvist et al. 2019).

8.3 DIRECTIONS FOR FUTURE RESEARCH

At the end of this work, we would like to develop on three main areas where further work would be needed to further advance the understanding, the operationalization, and the mainstream of ES, GBI and NBS concepts into planning:

1) Widespread use of big data in planning: while big data provide new and powerful ways of studying and improving coupled urban environmental, social, and economic systems to achieve urban sustainability (Ilieva & McPhearson, 2018; Kong, Liu, & Wu, 2020; Martí, Serrano-Estrada, & Nolasco-Cirugeda, 2019), the implication on the use of such data in urban planning are still far from being operationalized in urban policies. During our research we identify two main areas to which future research should point:
    i) Big data for better assessment of RES: development of data-driven climate and environmental services to be usable, comprehensible, and useful for local authorities, civil society, businesses, and citizens. While several open access sources currently exist (i.e Copernicus, MODIS NASA), the use of the extensive amount of data they produce is somehow limited, hampered by the complex mechanism of software interpolation needed for their usage. While within this work, where we made use of MODIS data to calculate local evapo-traspiration and we are currently exploring Copernicus Sentil-3 data to extract NDVI values in Bologna to further explore ES microclimate contribution, we acknowledge that the complexity and the lack of clarity in terms of potential usage of such datasets could hamper researchers in non-specific disciplines and local authorities in making use of those continuous and high-resolution data. The development of climate and environmental services able to provide researchers and local authorities with usable data would largely contribute to enhance the quality of the made estimation. In this line, Google Environmental Insights explorer just released two new services (version Beta is now available for the

city of Los Angeles), that provide air quality data – hyperlocal, street by street air quality data through mobile air sensors – and Tree Canopy. The street-by-street air quality location, for instance, would largely contribute to better understand PM_{10} distribution around the city, and the relative contribution of ES in effectively filtering it. While these services are now open for cities to be involved, the EU Commission, though the new Horizon Europe programme, or by appointing single research institutes, could further develop on this, making use of the already available data collected through Copernicus.

ii) Big data for better assessment of CES: we acknowledge that CES flow and demand assessment methods is rapidly shifting from survey and questionnaire based analysis to social media and big data analysis (e.g. Calcagni et al. 2019; Guerrero et al. 2016; Hamstead et al. 2018; Lee et al. 2019; Tenerelli, Demšar, and Luque 2016). Nevertheless, while approaching this method, we encountered one main limitation related to the quality of the available dataset. In reaction to the Cambridge Analytica scandal, Facebook has restricted the access to its Application Programming Interface, thus limiting the access to Facebook owned social media (Facebook and Instagram). This new policy has damaged the possibility for independent researchers to study relevant topics in political and social behaviour (Mancosu & Vegetti, 2020) and left few possibilities to legally use such data. While social media data are extensively used for marketing and business purposes, to our experience and limited knowledge, accessing them from a research point of view could be quite hard. At the moment, while these data could be ethically used complying with privacy regulations and anonymization requests (EU GDPR, 2016), limitations are imposed by Facebook Terms of services. Making such high quality geo-referenced data available for research purposes would not just be incredibly valuable for ES research to better assess citizens ES demand and preferences, but it would also boost automatic, machine learning, image recognition and related technologies application in the field (Lee et al., 2019; Richards, Tunçer, & Tunçer, 2018).

2) Application of the proposed framework in medium and small-size cities: within this work we have developed and tested our approach in a medium size city (i.e Bologna with around 380.000 inhabitants) and in a big compact urban area (Barcelona with around 1.6 million inhabitants). While the proposed approach works well in the case studies identified, during

the work we reflect upon the possibility of applying such an approach to medium-small case studies (below 150.000 inhabitants). Future research should be developed in this field to assess whether the proposed approach would still be applicable in medium-small size cities (with reference, for instance, to data availability, resources, capacities of the local authorities) or in small towns in peri-urban or rural areas (with reference to the relative relevance of UGAs and related ES generated in peri-urban or rural areas, and to relevance of justice principles) or if it should be further tailored to respond to their diverse needs.

LIST OF REFERENCES

Almenar, J. B., Elliot, T., Rugani, B., Philippe, B., Gutierrez, T. N., Sonnemann, G., & Geneletti, D. (2021). Nexus between nature-based solutions, ecosystem services and urban challenges. *Land Use Policy*, *100*.

Andersson, E., Enqvist, J., & Tengö, M. (2017). Stewardship in urban landscapes. *The Science and Practice of Landscape Stewardship*, 222–238. https://doi.org/10.1017/9781316499016.023

Andersson, E., Langemeyer, J., Borgström, S., McPhearson, T., Haase, D., Kronenberg, J., … Baró, F. (2019). Enabling Green and Blue Infrastructure to Improve Contributions to Human Well-Being and Equity in Urban Systems. *BioScience*, *69*(7), 566–574. https://doi.org/10.1093/biosci/biz058

Andersson, E., Tengö, M., McPhearson, T., & Kremer, P. (2015). Cultural ecosystem services as a gateway for improving urban sustainability. *Ecosystem Services*, *12*, 165–168. https://doi.org/10.1016/j.ecoser.2014.08.002

Baró, F., Calderón-Argelich, A., Langemeyer, J., & Connolly, J. J. T. (2019). Under one canopy? Assessing the distributional environmental justice implications of street tree benefits in Barcelona. *Environmental Science and Policy*, *102*(June), 54–64. https://doi.org/10.1016/j.envsci.2019.08.016

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S. B., Cundill, G., … West, P. (2012). Toward Principles for Enhancing the Resilience of Ecosystem Services. *Ssrn*. https://doi.org/10.1146/annurev-environ-051211-123836

Calcagni, F., Amorim Maia, A. T., Connolly, J. J. T., & Langemeyer, J. (2019). Digital co-construction of relational values: understanding the role of social media for sustainability. *Sustainability Science*, *14*(5), 1309–1321. https://doi.org/10.1007/s11625-019-00672-1

Colding, J., & Barthel, S. (2013). The potential of "Urban Green Commons" in the resilience building of cities. *Ecological Economics*, *86*, 156–166. https://doi.org/10.1016/j.ecolecon.2012.10.016

Dickinson, D. C., & Hobbs, R. J. (2017). Cultural ecosystem services: Characteristics, challenges and lessons for urban green space research. *Ecosystem Services*, *25*, 179–194. https://doi.org/10.1016/j.ecoser.2017.04.014

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., … Folke, C. (2019). Sustainability and resilience for transformation in the urban century. *Nature Sustainability*, *2*(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P., McDonald, R.I., Parnell, S., Schewenius, M., Sendstad, M., Seto, K.C., Wilkinson, C. (Eds.), 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportu- nities. Springer

EU Commission. (2019). *The European Green Deal*. https://doi.org/10.1017/CBO9781107415324.004

Fischer, A., & Eastwood, A. (2016). Coproduction of ecosystem services as human-nature interactions - An analytical framework. *Land Use Policy*, *52*, 41–50.

Fumagalli, N., Fermani, E., Senes, G., Boffi, M., Pola, L., & Inghilleri, P. (2020). Sustainable co-design with older people: The case of a public restorative garden in Milan (Italy). *Sustainability (Switzerland)*, *12*(8), 3166. https://doi.org/10.3390/SU12083166

Gascon, M., Mas, M. T., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. *International Journal of Environmental Research and Public Health*, *12*(4), 4354–4379. https://doi.org/10.3390/ijerph120404354

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, *86*, 235–245. https://doi.org/10.1016/J.ECOLECON.2012.08.019

Grimm, N. B., Faeth, stanley H., Golubiewski, N. E., Redman, C. L., Wu, Jianguo, Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities.pdf. *Science*, *319*, 756760.

Guerrero, P., Møller, M. S., Olafsson, A. S., & Snizek, B. (2016). Revealing cultural ecosystem services through instagram images: The potential of social media volunteered geographic information for urban green infrastructure planning and governance. *Urban Planning*, *1*(2), 1–17. https://doi.org/10.17645/up.v1i2.609

Hamstead, Z. A., Fisher, D., Ilieva, R. T., Wood, S. A., McPhearson, T., & Kremer, P. (2018). Geolocated social media as a rapid indicator of park visitation and equitable park access. *Computers, Environment and Urban Systems*, *72*(February), 38–50. https://doi.org/10.1016/j.compenvurbsys.2018.01.007

Hansen, R., Olafsson, A. S., van der Jagt, A. P. N., Rall, E., & Pauleit, S. (2019). Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators*, *96*(November 2016), 99–110. https://doi.org/10.1016/j.ecolind.2017.09.042

Haines-Young, R., Potschin, M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D., Frid, C. (Eds.), Ecosystems Ecology: a New Synthesis. Cambridge University Press, Cambridge, pp. 110–139.

Hegetschweiler, K. T., de Vries, S., Arnberger, A., Bell, S., Brennan, M., Siter, N., … Hunziker, M. (2017). Linking demand and supply factors in identifying cultural ecosystem services of urban green infrastructures: A review of European studies. *Urban Forestry and Urban Greening*, *21*, 48–59. https://doi.org/10.1016/j.ufug.2016.11.002

Honrado, J. P., Vieira, C., Soares, C., Monteiro, M. B., Marcos, B., Pereira, H. M., & Partidário, M. R. (2013). Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. *Environmental Impact Assessment Review*, *40*(1), 14–24. https://doi.org/10.1016/j.eiar.2012.12.002

Ilieva, R. T., & McPhearson, T. (2018). Social-media data for urban sustainability. *Nature Sustainability*, *1*(10), 553–565. https://doi.org/10.1038/s41893-018-0153-6

Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review. *Environmental Research*, *159*(August), 362–373. https://doi.org/10.1016/j.envres.2017.08.004

Kong, L., Liu, Z., & Wu, J. (2020). A systematic review of big data-based urban sustainability research: State-of-the-science and future directions. *Journal of Cleaner Production*, *273*, 123142. https://doi.org/10.1016/j.jclepro.2020.123142

La Rosa, D., Spyra, M., & Inostroza, L. (2016). Indicators of Cultural Ecosystem Services for urban planning: A review. *Ecological Indicators*, *61*, 74–89. https://doi.org/10.1016/j.ecolind.2015.04.028

Lee, H., Seo, B., Koellner, T., & Lautenbach, S. (2019). Mapping cultural ecosystem services 2.0 – Potential and shortcomings from unlabeled crowd sourced images. *Ecological Indicators*, *96*(September 2018), 505–515. https://doi.org/10.1016/j.ecolind.2018.08.035

Mancosu, M., & Vegetti, F. (2020). What You Can Scrape and What Is Right to Scrape: A Proposal for a Tool to Collect Public Facebook Data. *Social Media and Society*, *6*(3). https://doi.org/10.1177/2056305120940703

Maraja, R., Barkmann, J., & Tscharntke, T. (2016). Perceptions of cultural ecosystem services from urban green. *Ecosystem Services*, *17*, 33–39. https://doi.org/10.1016/j.ecoser.2015.11.007

Martí, P., Serrano-Estrada, L., & Nolasco-Cirugeda, A. (2019). Social Media data: Challenges, opportunities and limitations in urban studies. *Computers, Environment and Urban Systems*, *74*, 161–174. https://doi.org/10.1016/J.COMPENVURBSYS.2018.11.001

McPhearson, T., Andersson, E., Elmqvist, T., & Frantzeskaki, N. (2015). Resilience of and through urban ecosystem services. *Ecosystem Services*, *12*, 152–156. https://doi.org/10.1016/j.ecoser.2014.07.012

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., … Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *Science of The Total Environment*, Vol. 579, pp. 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., & Konijnendijk van den Bosch, C. (2017). *Nature-Based Solutions and Climate Change – Four Shades of Green*. https://doi.org/10.1007/978-3-319-56091-5_3

Peschardt, K. K., Schipperijn, J., & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). *Urban Forestry and Urban Greening*, *11*(3), 235–244. https://doi.org/10.1016/j.ufug.2012.04.002

Raymond, C. M., Gottwald, S., Kuoppa, J., & Kyttä, M. (2016). Integrating multiple elements of environmental justice into urban blue space planning using public participation geographic information systems. *Landscape and Urban Planning*, *153*, 198–208. https://doi.org/10.1016/j.landurbplan.2016.05.005

Richards, D. R., Tunçer, B., & Tunçer, B. (2018). Using image recognition to automate assessment of cultural ecosystem services from social media photographs. *Ecosystem Services*, *31*, 318–325. https://doi.org/10.1016/j.ecoser.2017.09.004

Rutt, R. L., & Gulsrud, N. M. (2016). Green justice in the city: A new agenda for urban green space research in Europe. *Urban Forestry & Urban Greening*, *19*, 123–127. https://doi.org/10.1016/J.UFUG.2016.07.004

Tenerelli, P., Demšar, U., & Luque, S. (2016). Crowdsourcing indicators for cultural ecosystem services: A geographically weighted approach for mountain landscapes. *Ecological Indicators*, *64*, 237–248. https://doi.org/10.1016/j.ecolind.2015.12.042

Webster, C. (2007). Property rights, public space and urban design. *Town Planning Review*, *78*(1), 80–101. https://doi.org/10.3828/tpr.78.1.6

ACKNOWLEDGEMENTS

Questo lavoro è frutto di attività di ricerca svolte principalmente presso l'Università di Bologna e supervisionate dalla Prof.ssa Simona Tondelli. È a lei che va il mio più sentito ringraziamento per avermi dato l'opportunità di proseguire i miei studi accogliendo, sempre con entusiasmo, la mia passione per il tema proposto. La ringrazio per il supporto scientifico e tecnico, ma soprattutto per la fiducia e la stima costantemente dimostrate in questi anni.

Il mio lavoro di ricerca si è arricchito negli anni attraverso la collaborazione con l'Institute of Sustainable Earth Science dell'Università di Plymouth, in particolare nella persona del Dr. John Martin che ringrazio per tutto il tempo dedicatomi, e con l'Institut de Ciència i Tecnologia Ambientals dell'Università Autonoma di Barcellona. Ringrazio il Prof. Francesc Barò e in particolare il Dr. Johannes Langemeyer per avermi accolta e per avermi aiutato a strutturare in maniera robusta le mie domande di ricerca, aiutandomi a prima a definirle, ma poi, soprattutto, a rimetterle in discussione. Un ringraziamento particolare va a Fulvia Calcagni, collega e amica, per avermi invogliato ad approfondire il tema della giustizia ambientale, che tanto mi ha arricchito nel mio percorso, e per il suo supporto indispensabile nell'elaborazione delle analisi spaziali.

Ringrazio le mie colleghe e i miei colleghi, i tirocinanti e i tesisti incontrati in questi anni, in particolare Elisa, Angela, Hanna, per il confronto, la condivisione e la collaborazione, e Francesca ed Andrea per il loro contributo prezioso. Ringrazio i revisori della tesi, per i preziosi commenti sulla prima versione di questo elaborato che mi hanno aiutato nella redazione finale di questo lavoro.

Ringrazio tutte le città che mi hanno ospitato nel tempo: Fano, Roma, Cadiz, Venezia, Leipzig, Gaziantep, Bruxelles, Las Palmas de Gran Canaria, Barcellona e Bologna, pensandole come sistemi socio-ecologici complessi. Le ringrazio perché mi spingono ogni giorno ad immaginarmi un luogo migliore dove vivere, fatto di contaminazioni di elementi che provengono da ognuna di loro.

Ringrazio le reti sociali delle mie città, fatte di persone che le hanno e mi hanno forgiato e accompagnato nel tempo. Ringrazio infine le loro reti ecologiche, verdi e soprattutto blu, per i benefici da loro generati durante il cammino.

Dall'incrocio di queste reti traggo, ogni giorno, lo stimolo per continuare a cercare e ricercare.

A Fernanda, Doriana e Olivia, per avermi trasmesso e regalato lo sguardo del passato, la forza del presente e l'entusiasmo del futuro.

Overall objective and reference to urban sustainability and ES/NBS	Relevance to urban sustainability		Role of nature in reaching the objective	
7th Union Environment Action (EAP) Programme to 2020	Recognized	Potential	Recognized	Potential
Objective: Guides European environmental policy towards 2020 and sets a long-term direction and a vision until 2050 (to live within the planet's ecological limits and in the healthy environment where biodiversity is protected, valued and restored). Relevant instruments are: Thematic priority objective 1 to protect, conserve and enhance the Union's natural capital: • Maritime spatial planning and integrated coastal management can play an effective role in coordinating sustainable use of marine waters and coastal zones when applying the ecosystem-based approach to the management of different sectoral activities in those areas. • Ecosystem-based approaches to climate change mitigation and adaptation which also benefit biodiversity and the provision of other ecosystem services. • In combination with the full implementation of the Nature Directives, further enhance natural capital and increase ecosystem resilience to offer cost-effective options for climate change mitigation and adaptation and disaster risk management. • Mapping and assessment of ecosystems and their services for data availability, and the 'no net loss' initiative (2015) will contribute to maintaining the stock of natural capital at a variety of scales. Thematic priority objective 3 to safeguard citizens from environment-related pressures and risks to health and wellbeing: • Measures to enhance ecological and climate resilience, such as ecosystem restoration and green infrastructure. Enabling framework priority objective : • Incorporating green infrastructure into related plans and programmes can help overcome fragmentation of habitats and preserve or restore ecological connectivity, enhance ecosystem resilience and thereby ensure the continued provision of ecosystem services, including carbon sequestration, and climate adaptation, while providing healthier environments and recreational spaces for people to enjoy. Biodiversity conservation through actions such as the reintroduction of nature into the urban environment and urban landscaping is increasingly evident	Low	High	High	High
The 8th Environment Action Programme - Turning the Trends Together 2030 - tbd				
Objective: the first communication regarding the 8th EAP, not published yet stresses that well-; it underlies the urgent need to act as several planetary boundaries have been crossed and as climate change, pollution, the loss of biodiversity and the accelerating demands on natural resources are jeopardising current and future generations' wellbeing and prospects; it insists that not acting now is causing high costs to the environment, human health, wellbeing and the economy;	N/A	High	High	High
European Green Deal – under development				
Overall objective: Outlines a commitment to tackling climate and environmental-related challenges and aims to make Europe climate-neutral, protecting the EU's natural capital and improving human well-being. Relevant instruments • Adopting a new, more ambitious EU strategy on adaptation to climate change. Work on climate adaptation should continue to influence public and private investments, including on NBS. It will be important to ensure that across the EU, investors, insurers, businesses, cities and citizens are able to access data and to develop instruments to integrate climate change into their risk management practices" • Strengthening 'a sustainable 'blue economy' to alleviate the multiple demands on land resources and tackle climate change, emphasizing	Medium	High	High	High

aquatic and marine resources and NBS, including healthy and resilient seas and oceans • Developing the Biodiversity Strategy for 2030 to halt the loss of biodiversity by protecting and restoring ecosystems and biodiversity, including proposals to green European cities and increase biodiversity in urban spaces. • Mobilising research and fostering innovation: o At least 35% of the budget of Horizon Europe will fund new solutions for climate, which are relevant for the Green Deal. o Four 'Green Deal Missions' will help deliver large-scale changes in e.g. climate change adaptation, oceans, cities and soil. The Horizon Europe programme will involve local communities in working towards a more sustainable future, in initiatives that seek to combine societal pull and technology push				

Biodiversity	Relevance to urban sustainability		Role of nature in reaching the objective	
Habitats Directive - 1992	Recognized	Potential	Recognized	Potential
Supports the protection, creation, restoration and sustainable management of habitats as part of Natura 2000, providing benefits to species, habitats and society (e.g. preserving a community's natural heritage, creating green recreational areas). Instruments include the designation of protected areas (Sites of Community Importance and Special Areas of Conservation) and Natura 2000 management plans.	Medium	Medium	High	High
Birds Directive – 1979 revised 2009				
Supports the conservation of all naturally occurring wild bird species in the territory of the Member States by employing measures to preserve, maintain and re-establish a sufficient diversity and area of habitats and biotopes for these species Instruments include: creation of protected areas and biotopes (such as Special Protection Areas for particularly threatened bird species and all migratory birds); upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones; re-establishment of destroyed biotopes. Particular attention is payed to wetland protection.	Low	Low	High	High
Green Infrastructure Strategy				
Aims to improve information, strengthen the knowledge base, promote innovation, and improve access to finance surrounding GI. The Strategy is implemented within the context of existing legislation, policy instruments and funding mechanisms. GI features in cities deliver health-related benefits such as clean air and better water quality. Healthy ecosystems also reduce the spread of vector-borne diseases. Implementing Green Infrastructure features in urban areas creates a greater sense of community, strengthens the link with voluntary actions undertaken by civil society, and helps combat social exclusion and isolation. They benefit the individual and the community physically, psychologically, emotionally and socio-economically.	High	High	High	High
EU Biodiversity strategy to 2030				
It is part of the European Green Deal and acknowledged that Biodiversity loss and ecosystem collapse are one of the biggest threats facing humanity in the next. Nature-based solutions and ecosystem services are both mentioned from the very beginning of the document Relevant Instruments: • New EU Nature Restoration Plan supporting the recovery of nature, limiting soil sealing and urban sprawl, and tackling pollution and invasive alien species • Recognized need of stronger implementation support and enforcement is required • Proposal for legally binding EU nature restoration targets • EU Soil Thematic Strategy in 2021. • New section dedicated to Greening urban and peri-urban areas • This strategy aims to stop the loss of green urban ecosystems. • Cities with a population above 20,000 citizens are called upon to develop Urban Greening Plans	High	High	High	High

• New European biodiversity governance framework In a stark comparison to the previous EU Biodiversity Strategy, cities are finally being recognised for the central role they play in safeguarding and enhancing biodiversity, and in providing green and blue corridors between larger areas of protected land.				

Water	Relevance to urban sustainability		Role of nature in reaching the objective	
Water Framework Directive (WFD)	Recognized	Potential	Recognized	Potential
Aims to achieve good ecological and chemical status of surface waters, and good quantitative and chemical status for groundwater. Recognizes the value of NWRM and supports implementation through the river basin management plans (RBMPs) and the accompanying programme of measures (PoM). Restorative NWRMs are particularly relevant for the PoM: e.g. restoring and recreating wetlands for water resource protection, natural bank stabilisation and re-meandering, the restoration of lakes, or floodplain restoration. NWRM are seen as GI applied to the water sector, as an alternative to grey infrastructure (Article 4.7) to achieve and maintain healthy water ecosystems and offer multiple benefits. In the agriculture sector, agricultural soil moisture conservation practices can be linked to agricultural NWRM.	Low	Medium	Medium	High
Floods Directive- 2007				
Establishes a framework for the assessment and management of flood risks, and aims at reducing adverse consequences of floods for human health, the environment, cultural heritage and economic activities. Floodplains are considered to be natural retention areas, with a preliminary flood risk assessment (Article 4.2) applied to assess potential risks. The flood risk management plans (Article 7) take into account the characteristics of the particular river basin or sub-basin, including the promotion of sustainable land use practices and improvement of water retention.	Low	High	Medium	High

Marine environment and coastal areas	Relevance to urban sustainability		Role of nature in reaching the objective	
Marine Strategy Framework Directive- 2008	Recognized	Potential	Recognized	Potential
Marine strategies shall apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations. - Sustainable development and use of marine and coastal space and resources; - Preservation, protection and improvement of the environment/conservation and recovery of ecosystems, including resilience to climate change impacts; - Enabling a sustainable economy and a strong, healthy and just society within environmental limits; Socio-ecological coastal areas are recognized within the directives as crucial socio-ecological systems, but the role of local authorities and communities is not explicitly mentioned in the directives, as well as the role of nature in supporting their transition towards sustainability and climate resilience. marine strategies shall apply an ecosystem-based approach to the management of human activities Programmes of measures and subsequent action byMember States should be based on an ecosystem-basedapproach to the management of human activities	Low	High	Medium	High

Proposal for a framework for maritime spatial planning and integrated coastal management				
Key principles: - Preservation, protection and improvement of the environment/conservation and recovery of ecosystems, including resilience to climate change impacts; - Enabling a sustainable economy and a strong, healthy and just society within environmental limits; - Preservation of coastal zones for present and future generations. - Conservation, restoration and management of coastal ecosystems, ecosystem services and nature, coastal landscapes and islands; Nevertheless, even though 40% of the population live in coastal regions, the role of cities and urban areas in sustainable management of coastal water is not directly mention in the proposal directive.	Low	High	Low	High

Climate	Relevance to urban sustainability		Role of nature in reaching the objective	
Climate Change Adaptation Strategy 2013	Recognized	Potential	Recognized	Potential
One of the three key objectives of the EU Adaptation Strategy focuses on 'climate-proofing' action at EU level by promoting adaptation in key vulnerable sectors such as agriculture, fisheries and cohesion policy and ensuring that Europe's infrastructure is made more resilient to the impacts of climate change. Its implementation is based on eight actions, including: • Action 2: A climate-action sub-programme was created under the 2014-2020 LIFE funding programme for the environment and targets the priority vulnerable areas aiming to increase their resilience. • Action 6: Guidance on how to further integrate adaptation into the CAP, the Cohesion Policy and the Common Fishery Policy has been prepared. It facilitates managing authorities and other stakeholders involved in programme design, development and implementation during the 2014-2020 budget period. • Action 7: Guidance was planned for authorities and decision makers, civil society, private business and conservation practitioners to ensure the full mobilisation of ecosystem-based approaches to adaptation for more resilient infrastructure. Building upon the success of its pilot project 'Adaptation strategies for European cities'16, the Commission will continue to promote urban adaptation strategies. Adaptation action by cities will, in particular, be developed in coordination with other EU policies following the model of the Covenant of Mayors, an initiative of more than 4000 local authorities voluntarily committed to improving the quality of urban life by pursuing EU climate and energy objectives.	High	High	High	High
Proposal for a European climate law to ensure climate neutrality by 2050				
The European Council has set building a climate-neutral, green, fair and social Europe as one of the main four priorities in its Strategic Agenda for 2019-2024 this proposal aims to establish the framework for achieving EU climate neutrality. No specific reference to urban areas is given in the proposal. Nevertheless, the European Climate Pact, to be launched in the last quarter of 2020, will include as one of the main areas to work tree-planting, nature regeneration and greening of urban areas.	Medium	High	Medium	High

Circular Economy	Relevance to urban sustainability		Role of nature in reaching the objective	
Circular Economy Action Plan 2015	Recognized	Potential	Recognized	Potential
Aims to help stimulate Europe's transition towards a circular economy, boost global competitiveness, foster sustainable economic growth and generate new jobs. It establishes a concrete and ambitious programme of action, with measures covering production and consumption to waste management and the market for secondary raw materials and a revised legislative proposal on waste. The proposed actions will contribute to "closing the loop" of product lifecycles through greater recycling and re-use to benefit the environment and economy.	Low	High	Medium	Medium
Proposal of a Circular Economy Action Plan focusing on sustainable resource use 2020				
The new Water Reuse Regulation will encourage circular approaches to water reuse in agriculture. The Commission will facilitate water reuse and efficiency, including in industrial processes. Furthermore, the Commission will develop an Integrated Nutrient Management Plan, with a view to ensuring more sustainable application of nutrients and stimulating the markets for recovered nutrients. The Commission will also consider reviewing directives on wastewater treatment and sewage sludge and will assess natural means of nutrient removal such as algae. The proposed European Urban Initiative, the Intelligent Cities Challenge Initiative, and the Circular Cities and Regions Initiative will provide key assistance to cities. Circular economy will be among the priority areas of the Green City Accord The Circular Cities and Regions Initiative (CCRI) is part of the new Circular Economy Action Plan and will focus on the implementation of circular solutions at local and regional scale. The CCRI will also provide a contribution to the implementation of the European Green Deal and the EU Bioeconomy Strategy. The Green City Accord will support cities in their efforts to achieve cleaner and healthier environments, thereby improving the quality of life of city dwellers. It will be launched in October 2020.	Low	High	Medium	Medium

Environmental Impact	Relevance to urban sustainability		Role of nature in reaching the objective	
Environmental Impact Assessment Directive (EIA)	Recognized	Potential	Recognized	Potential
An environmental impact assessment report requires the developer to provide information on measures envisaged in order to avoid, prevent or reduce and, if possible, offset likely significant adverse effects on the environment, as well as provide a description of the reasonable alternatives (for example in terms of project design, technology, location, size and scale) and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects. These requirements encourage more environmentally-friendly solutions.	High	Medium	Medium	High
Strategic Environmental Assessment Directive (SEA)				
The criteria to determine whether a project/plan/policy will negatively impact the environment would all favour greener solutions over traditional/grey infrastructure. By requiring all applicants (contractors and planners) to review 'reasonable alternatives' can encourage more natural or environmentally-friendly solutions to economic/social development.	Medium	High	Medium	High

Public procurement	Relevance to urban sustainability		Role of nature in reaching the objective	
EU Green Public Procurement (GPP) 2014	Recognized	Potential	Recognized	Potential
The use of the voluntary EU GPP criteria for public space maintenance has the potential to considerably reduce environmental impacts from	Medium	Medium	Medium	High

public space maintenance and can help stimulate demand for more sustainable goods and services (e.g. eco-innovations and nature-based innovations). Key GPP criteria: - Office Building Design, Construction and Management - Public Space Maintenance - Road Design, Construction and Maintenance - Waste-water infrastructure				

ES resilience aspects	Specification/Guiding questions for the assessment	Qualitative evaluation criteria	Relation to Biggs Resilience principle
Diversity consideration	*Biological diversity:* How are genetic, species and landscape level diversity addressed? How are interactions between species and/or ecological succession addressed? How is complementarity in the landscape addressed? *Social diversity:* How are the different socio-economic components of the urban areas analyzed? How are cultural and historical values considered? *Structural diversity:* How is urban structure (in terms of neighbourhoods' differences and components) considered? Spatial/temporal scale is considered?	High: All the components are addressed in detail. Biodiversity is addressed at genetic and species level; different relations in the system (e.g., food webs) are described as well as essential processes (e.g., nutrient cycling, hydrology); well consideration of different social groups, their current or potential employment rates, housing characteristics, growing population, and increasing immigration is taken into account in spatial and temporal scales; considered differences of neighbourhood/district characteristics Medium: several components of biodiversity in terms of species are addressed; no detailed reference to the different relation in the system. growing population and increasing immigration is mentioned without spatial or temporal scales, some information about different social groups and their employment rates are mentioned. No clear division in districts' characteristics Low: no components of biodiversity in terms of species are addressed; no reference to the different relations in the system. rowing population and increasing immigration not addressed or very vague. no reference to the spatial component of the socio economic and demographic characteristics	P1,P 4
Use of different knowledge spheres	What kind of knowledge is used? How is involvement of different stakeholders in planning, design, management, monitoring etc. addressed? Spatial/temporal scale is considered?	High: Different kind of knowledge have been used (i.e reference to scientific framework or existing studies, informal knowledge, previously acquired knowledge); detailed explanation and presentation of the stakeholders to be included in the different steps, collaboration pathways and different role clearly explained. Medium: Knowledge-base is not completely clear; some references to previous study but not comprehensive	P1, P5, P6

		assessment of the knowledge sphere included. Stakeholders presented in different details, collaboration mentioned, but not clear roles and methods Low: Knowledge base is fuzzy and not references. Not clear reference to stakeholders either to roles and methods of collaboration	
Physical connectivity	How is green and blue infrastructure (structures, nodes, networks, species migration etc.) addressed? How is mobility and physical accessibility addressed? How is information flow addressed? Spatial/temporal scale is considered?	High: Map of the existing blue and green infrastructure presented, evaluated and used as a base for further discussion on the topics; existing nodes, networks, and possibilities for species migration have been addressed. Concrete actions agreed and well presented to improve current infrastructures connectivity. Accessibility to the green and blue infrastructure is assessed and well considered. Physical nodes and mobility and transport scheme have been previously assessed and the results are integrated in the policy. Actions on how to improve it are considered. Medium: reference to the overall green infrastructure present but not clear the level of detail; existing nodes, networks and species migration mentioned; mention to future development of the structures, but no concrete actions mentioned. Accessibility to the spaces is considered but not detailed explained neither in present or future actions Low: reference to the overall green infrastructure present but not clear the level of detail; existing nodes, networks and species migration not mentioned; no mentions of future development of the structures. accessibility and connectivity are not consider neither as an assessment neither for future development	P2
Disturbance regimes	What disturbances are recognized? What responses are addressed (coping, adapting, transforming)?	High: disturbances have been identified and assessed with clear reference to spatial and temporal frame. Responses to disturbances have been clearly identified (i.e. action plans, strategy, etc.)– specify which disturbances and responses have been considered Medium: main disturbances have been identified, but there's no clear spatial and temporal frame. Responses to disturbances have also been considered, but not clear actions planned - specify which disturbances and responses have been considered Low: disturbances have not been identified, neither clear responses to possible events	P3, P4

Assessment of forecast, possible changes and uncertainty	What changes are recognised, e.g. climate, demographical, economic, political, technological innovation, human preferences and lifestyle (CES), tourism, housing, land use planning? Are changes in relation with future capacity and demand of ES considered and addressed? How are monitoring, evaluation and revision addressed? Spatial/temporal scale is considered?	High: main possible changes trend and scenario relevant for the city development and planning have been considered, they have been integrated and overlapped among them; monitoring, evaluation and revision methods and actions have been addressed. Possible changes in ES capacity and demand have been addressed, even if not explicitly mentioned as such. Medium: main possible changes, trend and scenario have been considered, with low level of detail and no integration among them; monitoring, evaluation and revision are mentioned but not explained in detail. Possible changes in ES capacity and demand are not clearly addressed, even if not explicitly mentioned as such. Low: main possible changes trend and scenario have not been considered, maybe mentioned but not assessed; no reference to monitoring evaluation and revision. Possible changes in ES capacity and demand are not addressed, neither implicitly.	P3, P4
System knowledge approach	How are the management steps of monitoring, evaluating, revising and adapting addressed? How are emergent signals captured? How are responses to changes addressed?	High: management steps of monitoring, evaluating, revising and adapting are well addressed. Responses to changes as well as emergent signals are well defined and integrated. Medium: management steps of monitoring, evaluating, revising and adapting are mentioned, but not clearly addressed as well as emergent signals. Responses to changes are not clearly defined and integrated. Low: no specific management steps of monitoring, evaluating, revising and adapting are mentioned neither emergent signals are addressed. Responses to changes are not defined and integrated.	P3, P4, P5
Institutional flexibility	In what ways is the approaches to GBI reactive or proactive? How are alternative approaches recognized? What kind of formulations are used, e.g. shall, should, recommend?	High: alternative approaches are considered and clear criteria for decision support are recognized. High degree of flexibility of the policy is recognized and structured. Medium: alternative approaches are recognized, bit not clear criteria to support decision are recognized. Flexibility and adaptation of the policy are considered but not addressed. Low: alternative approaches are not recognized; possible flexibility of the policy has not been considered	P3, P4, P5
Poly centric governance	How is governance organised (centralised/decentralised, single actor/multiple actors, sector divided, strong/weak linkages across levels, sectors and actors)?	High: multi-stakeholders and participatory process have been set up from the policy development and have been integrated in the strategy/action plans for future collaboration. Governance models are clearly defined and flexible. Responsibility and roles are also well explained. Collaboration among stakeholders is well defined; dedicated	P1,P2, P6,P7

	How is collaboration between actors addressed? How is responsibility organised?	tools instruments and methods have been developed. Medium: multi-stakeholders and participatory process have been set up but not clearly integrated and explained in the overall process. Governance models are defined but with low level of details. Roles, responsibilities and competences are implicitly considered but not clearly defined in the text. Collaboration among stakeholders is mentioned but dedicated tools instruments and methods are not clearly defined. Low: multi-stakeholders and participatory process are not integrated and explained in the overall process. Governance models, responsibility and roles are fuzzy and not clearly identified. Not clear how stakeholders will cooperate

N	Name of the relevant document
1	Ajuntament de Barcelona. Àrea d'Ecologia Urbanisme i Mobilitat. 2015. "Guide to Living Terrace Roofs and Green Roofs."
2	Ajuntament de Barcelona. Àrea d'Ecologia Urbanisme i Mobilitat. 2017. "Trees for Life : Master Plan for Barcelona's Trees 2017 - 2037."
3	Ajuntament de Barcelona. 2014. "Plan Del Verde y de La Biodiversidad de Barcelona 2020."
4	Ajuntament de Barcelona. 2018a. Departament de Resiliència Urbana, Gerència d'Ecologia Urbana, 100 Resilient Cities (Associació) "Barcelona : Preliminary Resilience Assessment."
5	Ajuntament de Barcelona. 2018b. "Pla Clima 2018-2030."
6	PGM/PGU - Metropolitan Planning regulation of the general plan - "PDU- QUADERNS PDU METROPOLITÀ 03 - Urbanism of open spaces: landscape, leisure and production
7	Ajuntament de Barcelona 2018. Pla estratègic dels espais litorals de la ciutat – under development
8	Ajuntament de Barcelona 2015, Comissió d'Hàbitat Urbà i Medi Ambient, Gerència Adjunta de Medi Ambient i Serveis Urbans, Àrea d'Hàbitat Urbà Pla de millora de la qualitat de l'aire de Barcelona 2015-2018
9	Milan Urban Food Policy Pact, Ajuntament de Barcelona, 2015. Pacto de Milán de política alimentaria urbana
10	Ajuntament de Barcelona 2016. Omplim de vida els carrers, la implantació de les superilles a Barcelona : mesura de govern- The superblock plan

ANNEX IV LIST OF PARTICIPANTS TO THE WORKSHOP HELD IN BARCELONA

Nº	Affiliation	Sector
1	Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), (organizer)	Research
2	Ajuntament de Barcelona, Departamento de Resiliencia Urbana (co-organizer)	Public Administration
3	Alma Mater Studiorum - Università di Bologna (co-organizer)	Research
4	ENT, medi ambient i gestió (co-organizer)	SME
5	Ecologic Institute (co-organizer)	Research
6	100 resilient cities	Research
7	Generalitat de Catalunya - DTES	Public Administration
8	Àrea Metropolitana de BarcelonaAMB	Public Administration
9	Diputació de Barcelona	Public Administration
10	Suez	Industry
11	LEITAT	Research and Innovation
12	Universitat Oberta de Catalunya	Research
13	Agència de Salut Pública de Barcelona - Generalitat de Catalunya	Public Administration
14	Cátedra UNESCO de Sostenibilidad-	Research
15	Universitat Politècnica de Catalunya - UPC-BarcelonaTech	Research
16	Universitat Internacional de Catalunya UIC	Research
17	Fàbrical del Sol	Public Administration environmental education centre
18	Som Natura	NGO – civil society
19	Elrisell	SME Consultancy
20	Eix Verd	SME Social enterprise
21	Oficina Catalana del Canvi Climàtic	Public Administration and research

22	Barcelona Cicle de l'Aigua SA (BCASA)	Public Administration
23	Agència de Salut Pública de Barcelona	Public Administration
24	Universitat de Màlaga	Public Administration
25	Barcelona Regional	Public Administration
26	Ajuntament de Sabadell	Public Administration
27	Huertosinthesky	NGO – civil society

1# Scenario: Ageing and shrinking population

(moderator: Claudia de Luca , notes: Katriona McGlade)

- Barcelona 2025; outmigration of young population and ageing of resident population emerged as main issues.
- The pressures on health, mobility, housing, job availability, and social services have substantially increased.
- Elders suffer high levels of depression and loneliness, lacking opportunities to engage (socially or economically), and in public health and wellbeing.
- City is lacking accessible open green spaces, as these have capacity to provide manifold social and environmental benefits.

Barcelona 2025; As a consequence of the climate and economic crisis in the last 15 years, the city lost around 200.000 inhabitants, mostly young educated people, resulting in a resident population of around 1.4 million[5]. Also, birth rate has decreased substantially over the period, as young people continue facing serious barriers in access to secure jobs and affordable housing, with direct consequences on household formation and natality levels.

As a matter of fact, elderly people account now for over 27% of the resident population (compared to 21% in 2016) generating an increased pressure on urban systems, such as health, mobility and social services among others. In terms of household composition, this is resulting in an increasing number of elderly people living alone, as well as in new and crowded retirement homes managed by the City Council, private entities and third sector organisations. The Agència de Salut Pública de Barcelona (ASPB) reports that depression rates especially among the elderly population are becoming alarming, calling for concrete actions to address the challenges of ageing population in an integrated way.

Within this context, scientific evidences on the positive links between health, social interaction, and green public spaces, are becoming increasingly acknowledged by policy-makers with competencies over public health, seeking to foster the use of green and public spaces by local population, especially elderly people. However, in a high-density urban area, with limited space for urban regeneration and rapidly changing demographic patterns, these efforts require integrated and creative solutions across several policy areas.

2# Scenario: Enhanced tourism

(moderator: Maria Gómez, notes: Luis Campos)

- Barcelona 2025; mass tourism is a source of wealth but also of complex challenges.
- The pressures on housing, services, and urban space availability as well as on urban environment have substantially increased.
- This has resulted in rising prices, increase in illegal activities, overcrowded and degraded open spaces, and in changing attitudes of residents living in affected central neighbourhoods.
- Affected residents are deprived of available green spaces and beaches for recreation. Several local movements have emerged and started to act.
- Policy interventions are needed in order to re-establish the availability open spaces and related benefits, fostering the wellbeing of residents.

[5] http://www.bcn.cat/estadistica/angles/dades/tpob/projeccions/pob/prpob/base2013/bcn/t111.htm

Barcelona in 2025; tourism further increased. The city now received more than 30million annual visits, in average more than 160,000 per day[6]. Hospitality business and related tourism offers have grown substantially. Tourism belongs to the most important economic activities in Barcelona, providing income to a large share of the residents. Nevertheless, the negative impacts of tourism are being progressively questioned.

From an environmental point of view[7] – carbon footprint, water usage, waste disposal – mass tourism is hardly sustainable in a very compact and dense city as Barcelona. From a social point of view, attitude of some resident groups has drastically changed in the last 15 years.

As from 2015, the city council has started developing measures to regulate mass tourism (e.g. diversifying offers, licence limitation, tourism taxation, etc.). Nevertheless, it did not prove to be effective on some of the main issues: housing prices (20% rise in central neighbourhoods), public transport, and especially access to open spaces and cultural sites – Barceloneta beach, Ciutadella, Parc Guell, Mont Juic, public squares and ramblas. Also, a trend of 'urban nature tourism' emerges, flooding parks in Barcelona with birdwatchers, picknickers, beerdrinkers.

The wellbeing of residents has suffered, as they are deprived of the beneficiary effects coming from the nature experience. Also, affected green spaces are now subjects of degradation. Residents started to avoid using these green spaces and beeches, as they are overcrowded and noisy.

An integrated policy action is needed in order to foster the social life, to enable access to recreation in the city, and to improve health and wellbeing of its citizens.

3# Scenario: Gender inequality

(moderator: Johannes Langemeyer, notes: Filka Sekulova*)*

- Barcelona 2025; Public spaces are dominantly used by male population due to certain changes in perceptions and behaviours. Equal access to green and open public spaces is questioned and gender issues are increasingly raising.
- An increasing number of women is reporting negative experiences from their visits of open spaces, also due to misperception and disinformation. The "stories" are spreading fast.
- The access to green spaces by women became limited, as they perceive them as unsafe.
- In result, the female population is deprived of benefits related with urban nature.
- Policy interventions are needed to re-establish the accessibility to open spaces and related benefits.

Barcelona in 2025. the number of visits to green spaces by female population has declined in the last years, resulting in more "homogenized" male-oriented user groups. This trend emerged as a product of changing behaviours and perceptions of public spaces in Barcelona, especially among women. Some serious questions related to gender equity have been put forth.

---

[6] This means a yearly increase by about 1% since 2017.
http://ajuntament.barcelona.cat/economiatreball/sites/default/files/documents/mesura_de_govern_mobilitat_0.pdf

7 Rico A. et al., 2019. Carbon footprint of tourism in Barcelona, Tourism management, 70 (2019), 491-504

Negative experiences, including ambushes, thievery, sexual harassment, and other dangerous encounters have been reported, whereas the victims are being predominantly women. Even though these encounters are rather rare, the stories continue to spread. The public community, and specifically women, widely perceive the open spaces as unsafe. Especially larger green spaces that are difficult to control, such as Collserola, Montjuic, Park Güell, or Tres Turons, are evoking negative thoughts and anxiety. Besides female population, families and elderly have started to avoid these areas too.

The accessibility to nature experience in the city has become limited as the feeling of safeness has dropped extremely. Changing perceptions further affect behaviours; concerned user groups (mostly women and elderly) are feeling threatened, what induces their suspicious behaviour and tendency to avoid social encounters in the public spaces. Social interactions and gender equity are disrupted. In fact, green spaces are considered by women to be the most unsafe urban areas[8], due to crime and violence that they are exposed to.Female users are deprived of the benefits linked to the green space use as result of realities narrated above. To re-establish social equity in terms of the opportunities to experience urban nature for all, policy interventions will be necessary.

4# Scenario: Global warming

(moderator: Francesc Barò*, notes:* Andoni Gonzales)

- Barcelona 2025; climate change has intensified and is affecting the city and its residents.
- Increase in the number of torrid days, droughts, fires, rain-shortages, and water scarcity represent and immense challenge for the future life in the city. Some residents are affected more than other; especially vulnerable groups are elderly, children, and pregnant woman. Similarly, heavily build-up areas are affected the most.
- An increased importance of friendly and climate-resilient open spaces is highlighted.
- Policy interventions are needed in order to preserve and foster the capacity of provisions originating from open spaces, as these are becoming critically scarce

Barcelona 2025; Global feedback processes have accelerated the global warming trend to an extent unpredicted by most climate scientists. Barcelona became a critically endangered region, exposing its population to risk and uncertainty. Rapidly changing climate manifests its power through a high variability and frequent occurrence of extreme events.

A number of torrid days (reaching over 33°C) and the duration of droughts increased eight-fold. Intensive urbanization amplifies the urban heat island effect, making the build-up area hotter by 20°C comparing to the surrounding green areas[9]. The number of deaths counts for 2000 human lives per year due to the heat in Barcelona only[10]. Districts with the lowest coverage of green spaces are hit most heavily, as they become unbearably hot. These areas correspond with the poorer population, whereas elderly, children and pregnant women are the most vulnerable groups. Tropical nights exhausts people as they are not able to have a needed rest after a torrid day. Heat waves cause premature births, physical and mental

[8] https://ajuntament.barcelona.cat/dones/sites/default/files/documentacio/17_661_web_bcn_v2_0.pdf

[9,8] http://lameva.barcelona.cat/barcelona-pel-clima/en

diseases, but also financial shortages of poorer residents due to intense use of cooling technologies; also, resulting in higher energy use and thus intensifying the climate change.

At the same time, the city experiences severe rainfall shortages and thus water scarcity. Furthermore, fire hazards concern not only the Collserola, but appears in the neighbourhoods of Vallvidrera, Tibidabo i les Planes, Horta, Canyelles, or Torre Baró, where thousands of people reside.

By contrast, rainfall gains on intensity in form of a storm events which frequently flood the city; floods and landslides are threatening residents and causing ample economic damages. A 72% of impermeable surfaces[11] and lack of climate-resilient green spaces in Barcelona are boosting impacts to maximum. Another critical water-related issue will soon emerge on the coastline, where the sea level may rise by additional 1m and start to flood the recreational areas.

Citizens' health and wellbeing started to decrease. A discomfort from heat, droughts, fires, or storm events, has led to a higher demand for friendly and resilient open green spaces. Integrated policy action is required to preserve ecosystem provisions that are necessary for security and wellbeing of citizens.

[11] https://ajuntament.barcelona.cat/ecologiaurbana/en/what-we-do-and-why/energy-and-climate-change/climate-plan

ANNEX VI ECOSYSTEM SERVICES ASSESSMENT WORKSHOP EXERCISE

Objectives

This exercise aims to reveal potential shifts in the demand and supply of ES exposed by the scenarios - possible futures.

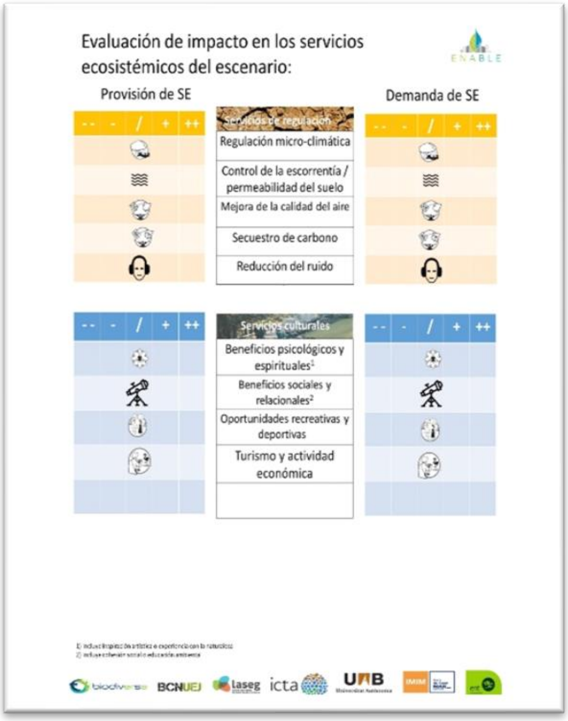
Materials

Scenario print-outs 50x (10x4 for participants + 2x4 for moderators); Printed images 12x (3 per scenario); Impact assessment poster 4x (1 per group); Sticky points 40x (10 per group); Markers in different colors 16x (poster operations)

Description

After the introducing presentation by Johannes and Claudia, participants are divided into 3 or 4 heterogeneous groups to work independently on the assigned scenario *(1 per group)*. Each group is formed by the maximum number of 10 participants (depending on the final list of participants). Group sessions are operated by the facilitator and the note-taker *(1 and 1 per group)*. The facilitator presents the scenario *(5min)*, supported by the images placed on the table and printed scenario materials, including bullet points as a summary.

Each group will then start to work on the ES impact assessment *(Figure 1)*, represented by selected list of ES (icons) placed on the scale. Participants are asked to assess the shifting ES supply/demand reflecting on the presented scenario. Each group receives sticky points (one per ES to be assessed + 1 extra sticky point for potential suggestions of different ES by participants) that are used to indicate the shifting supply/demand for selected ES (by participants). If no consensus is made within a group on the placement of certain ES on the scale (which ES and how they shift), moderator will start the voting.



Ecosystem Services impact assessment poster used in the workshop poster

Ecosystem Services categories presented in the workshop

ANNEX VII POLICY OPTIONS WORKSHOP EXERCISE

Objectives

This part aims at understanding how current policies and strategies can work to ensure the ES provisions in the long-term perspective – by discovering resilient policy options.

Materials

Post-its 40x and pens 40x (the individual exercise); Policy development poster 4x (1 per group); Markers in different colors 16x (poster operations)

Description

Participants will be asked to individually reflect on the ES impact assessment within the given scenario, and to propose a policy-oriented action (the same groups are maintained). First, each participant receives one post-it from the facilitator. Then, participants are asked to write their name and the acronym of the organization they belong to on their post-it (this will allow facilitators to understand if there are certain 'clusters' of stakeholders). This exercise is individual *(5min)*, where participants are asked the following reflection remark:

"Please indicate the ES that you consider as most important to be addressed. Name one measure that you find most promising in order to guarantee the future supply of ES under the scenario of change you worked with."

After the individual exercise, participants briefly present their ideas one by one. Meanwhile, moderator collects filled post-its and start to cluster the written ideas on the poster (*Figure 2*) according to common features (i.e. addressed policy sectors, addressed ES, etc.) *(10 minutes)*. When the brief presentations are over, and all ideas are placed on the flipchart, moderator triggers the discussion among the participants referring to collected ideas *(30 minutes)*. The discussion is directed by the following reflection remarks:

"How can the measures be integrated into existing policies. What themes, sectors, and policies are most relevant to be addressed? What policy action/intervention would you propose to improve "resilience" of current policies?"

During the discussion, moderator keeps incorporating the new ideas and observations in the poster – as these may arise. This is done by operating with the marker and by replacing around the post-its.