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Ecological and Digital Transition in Cities

Measuring Ecosystem Services for Urban Planning and Design

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Preface

Planning the Transition for Cities and Territories: Innovative Approaches and Research Trajectories

The high level of uncertainties and complexity under the continuous shocks and stresses that have arisen in the last years have led the European Union to set out a strategic agenda (2024–2029) grounded on three main pillars [1]: a free and democratic Europe, a strong and secure Europe, a prosperous and competitive Europe. Such strategic pillars influence the EU's complex set of policies built upon an integrated policy approach that simultaneously addresses environmental (biodiversity, climate change, energy), economic (technology and digitalization, industrial transformative development, strategic investments, circular economy), and social (cohesion) dimensions in the context of climate neutrality and resilience-oriented development. The environmental dimension has assumed centrality in the complex set of EU policies. Natural capital protection and restoration, biodiversity enhancement, and energy and climate change issues are at the core of the economic restructuring processes [2]. They are pursued under the overall main objective of reinforcing social, economic, and territorial cohesion. The recent Nature Restauration Law [3] is a central element of the EU Biodiversity Strategy, whose main aim is to restore natural resources to increase biodiversity and secure ecosystem services (ESs), contributing to limiting climate change and increasing Europe's resilience. These elements are also included in the European Green Deal, the ambitious plan to transform Europe into the first climate-neutral continent. The Green Deal is a strategic framework to accelerate the transition toward a carbon-neutral economy by decoupling economic growth from resource exploitation. It sets ambitious objectives by 2050, promoting sustainability and resilience in several thematic areas through an integrated approach [2]. Activating such a transformative shift generates a new demand for sustainability in cities—which catalyzes restructuring processes—for balancing economic development and natural capital enhancement crucial for human well-being. The pressures generated on natural ecosystems are harnessing their ability to produce the ESs vital for humans [4–6], and urbanization processes have simultaneously increased the demand for natural capital in cities [7]. From regulating climate and air quality to enhancing biodiversity and recreational spaces, ESs are nowaday integral to urban health and sustainability [8, 9]. However, integrating these services into the urban fabric requires innovative thinking and a departure from conventional planning paradigms [10]. ESs include providing services like food and water, regulating services such as climate regulation and flood control, cultural services providing recreational, aesthetic, and spiritual benefits, and support services, including nutrient cycling and soil formation [10]. Also, in the urban context, implementing ESs can mitigate urban heat islands, improve air and water quality, and enhance the overall well-being of city dwellers.

The main challenge lies in effectively integrating these services into urban planning and policy for their reinforcement by considering the complex interdependencies between human and natural systems [11, 12]. In this direction, this book advocates for a paradigm shift in planning the transition of cities and territories, focusing on the centrality of natural capital for their future. A critical aspect of such integration lies in digital technologies and data-driven approaches. The advent of big data, urban informatics, and advanced modeling techniques (artificial intelligence and machine learning) offers unprecedented opportunities in this direction. By leveraging these technologies, planners and policymakers can make informed decisions that optimize the delivery and benefits of ESs [13]. This data-driven approach enhances the precision and efficiency of urban planning and facilitates the monitoring and evaluation of ecosystem service outcomes over time.

These elements pose a fundamental question: What kind of planning is required during times of transition? How can it strengthen the sustainable and resilient development of cities and regions amidst persistent shocks and pressures? How can it revolutionize its methodologies and champion innovative approaches to address such complex challenges?

Urban planning encounters an impasse phase [14]. Starting from late 2000, with the financial crisis of 2008, the role of planners and the ability to plan to preconfigure sustainable futures dealt with the neoliberal agenda [15], which has shown during and after the pandemic that inequalities, democratic gaps, and social exclusion increased. Rapid urban growth in recent decades has led to a dichotomy between competitive development and social and environmental issues [15]. Economic development, driven by neoliberal approaches, has misaligned welfare principles in urban planning, emphasizing more market-oriented dynamics [16, 17]. This has increased social, economic, and environmental vulnerabilities, and traditional urban transformation practices aimed at boosting competitiveness have become inadequate, especially in the face of climate change, emphasizing the pressing request for equity in transitioning. Since the 1990s, urban regeneration has emerged as a crucial element in urban planning, integrating social, economic, and environmental aspects to enhance city sustainability and resilience [18]. The evolution of urban regeneration and approaches has contributed to developing new forms of public-private partnerships, citizen-administration interactions, and mixed-use developments. These strategies aims to promote economic and social inclusion and catalyzed environmental sustainability. Urban regeneration shows the potential to address global challenges and support the local ecologicla, digital, and inclusive transitions [19]. Such characteristics open innovative perspectives on planning cities' transition in stressing adaptive and regenerative approaches in urban planning: two forward-thinking approaches that aim to respond to current challenges and anticipate future needs beyond sustainability and resilience.

Adaptive approaches focus on flexibility, enabling cities to respond to changes and uncertainties, emphasizing the ability of urban systems to quickly adapt to new conditions and continue to function effectively [20, 21]. Urban plans in this context involve urban regeneration initiatives that aim to create strategies and interventions to withstand and recover from various shocks and stresses. The goal is to increase urban resilience and address critical vulnerabilities. By using data-driven approaches to construct new scenarios, effective, flexible urban strategies can be developed to adapt to different conditions. This requires dynamic and iterative processes to ensure that urban plans remain relevant and effective over time. Engaging stakeholders, including citizens, businesses, and policymakers, is also crucial to ensure cohesion and support for adaptive measures.

Regenerative approaches go beyond sustainability, including it in a systemic, holistic, and integrated approach aimed at bouncing back development conditions under an acceptable threshold represented by the earth's capacity to fulfill human needs [22]. At the core of these approaches lies the idea of creating the conditions for a different and more balanced nature-human interaction centered on circular metabolism [23]. Applying such concepts in urban planning processes and tools is challenging. The urban population is constantly growing and will continue to grow in the next decades, demanding natural capital [7] but also for housing, energy, transportation, increased economic activities, and urban infrastructures. Planning and Policies instruments have the difficult task of accommodating such needs and, at the same time, deploying suitable solutions for sustainable development. Concepts such as "density," "compact development," and "mixed-use" are being revisited in an attempt to optimize urban environments and reverse the negative trend activated by economic-growth-oriented models.

The adaptive and regenerative approaches outline a clear tendency to revise and innovate planning practices for cities and territories in response to the demand for resilience (social, economic, and environmental) and sustainability (which embrace a new dimension under the regenerative conceptualization). Both approaches are somehow interrelated and share the common root of preserving and restoring natural capital. In this direction, understanding the complex interaction between nature and human activities characterized by the social, built, and natural capital components provides the ground for upgrading planning approaches and practices. In such interactions, ESs play a central role in human well-being, and can drive policies, planning, and planning instruments in the short, medium, and long term.

The pace and intensity of the pressures generated by climate change call for urgent mitigation and adaptation measures, and cities can contribute to finding solutions [24]. They host most of the world's population, concentrate most of the emissions of pollutants, and are the places of socio-economic inequalities [4]. At the same time, intervening in cities offers the chance to address such complex issues and generate positive "spill-over" effects in the urban-rural relationship by rebalancing the pressures of urbanized areas on the surrounding context through the deployment of innovative solutions [4, 5].

Therefore, the book explores the potential of data-driven methodologies for developing innovative urban planning practices and approaches for resilient, sustainable, and equitable cities facing the challenge of planning their ecological, digital, and inclusive transition. In the face of unprecedented urban growth and urbanization side effects, environmental challenges, and socio-economic disparities, cities worldwide are at a critical point. The call for an integrated approach that combines ecological sustainability with economic development by ensuring social inclusion and equity has never been more pressing. The book aims to engage the discussion on how to shape the ecological, digital, and inclusive transition of cities and territories towards sustainability and resilience, starting from the centrality of urban planning in the promotion of such a transformative development. Primarily, it targets the academic and policymakers communities that are navigating the transition's complexity under the challenges arising after the pandemic, such as geopolitical events, political instability, energetic issues, and democratic and representative challenges, which are questioning the essence of the economic development paradigm pursued so far and calling for reshaping development trajectories through innovative planning approaches.

The book reflects the ongoing synergistic activities of three Next Generation EU-funded projects under the Italian National Recovery and Resilience Plan (NRRP). The Pilot Project 4.6.1 of the Tech4you Innovation Ecosystems (Mission 4 - Component 2 - Investment 1.5), the ECO-SET project - A Multidisciplinary approach to plan ECOsystem SErvices for cities in Transition (Mission 4 - Component 2 - Investment 1.1), and the PLANET – Planning ecosystem services for cities in transition (Mission 4 - Component 2 - Investment 1.2). All these projects collectively aim to explore and better understand how to promote a data-driven approach in urban planning and design stemming from the relevance of natural capital and biodiversity in facing the challenges of climate change for the transition of cities and territories. The Pilot Project 4.6.1 of the Tech4You Innovation Ecosystem focuses on innovative solutions for addressing urban and territorial fragmentation, particularly in southern Italian regions (Basilicata and Calabria). The project aims to implement dynamic, site-specific interventions that cater to the evolving demand for sustainable and effective transformations by promoting green and blue infrastructures. These interventions also address the challenges of depopulation and decentralization, enhancing the urban-rural connection by developing AI-based predictive models and scenarios for developing climate-resilient urban planning. The ECO-SET project focuses on developing a data-driven approach to urban planning to enhance ESs within urban transformations. Based on the Natural Capital Approach, according to the principles of biodiversity, ESs allow for improving the supply of goods and services for the well-being of society by incorporating the ability to adapt to both current risks and future climate change, reducing the ecological footprint and ecological debts, while improving resilience, health and quality of life. The scope is to operate a technological nexus between Territorial Intelligence (TI) and zoning rules to frame planning models for handling the complex systems involved in climate-proofing toward a user-tailored perspective, in which urban regeneration plays a central role for future development policies. The ECO-SET project adopts an interdisciplinary approach to experiment with the potential of data-driven urban planning in supporting the innovations necessary to make ESs a routine part of urban and infrastructure development by municipalities. The PLANET project delves into the mechanisms that trigger urban regeneration nurtured by socio-ecological-technological dynamics. This project highlights the need for alignment between digital and ecological transitions, which—by nature and characteristics—inherently follow different dynamics and time trajectories. A new perspective on urban regeneration is emerging, focusing on reducing pressures on natural ecosystems and characterized by strategic drivers such as ESs and key enabling technologies (KETs) for facilitating the transition of cities and more equitable development. Together, these projects form a collaborative effort shaping promising research trajectories in the urban planning field, providing interesting insights for evolving and innovating urban planning practices.

The proposed comprehensive integration of knowledge and methodologies is investigated to address the multifaceted challenges of urban and territorial transitions from a planning perspective. This research framework clearly shows the relevance and importance of the topics under investigation for the future of cities and regions and their sustainability and resilience. This transition pathway pivots around the three main dimensions of sustainability, namely the social, economic, and environmental, and the three main components of human life on this planet, namely the natural, social, and built capital. Dimensions and capital are the two key elements that planning has to consider for ensuring stable conditions for the current and future generations.

The abovementioned research trajectories are aligned with the evolution of the policy context in the European Union, characterized by the aim to facilitate the recovery and increase resilience after the pandemic. A policy effort finds operativeness in the National Recovery and Resilience Plans (NRRP), whose aim is to facilitate the ecological, digital, and inclusive transition of the Union. At the core of this path, the Next Generation EU instrument was introduced for recovery after the pandemic, combined with the ordinary resources of the programming framework 2021–2027 to boost investments for the transition in EU countries. However, the instrument thought to address gaps and unbalances after the pandemic, has been challenged by other rising shocks and stresses, which have contributed to its revision, such as geopolitical events, energetic issues, and social impacts of the envisaged transition with the risk to hamper the achievement of the ambitious goals of the EU Green Deal: decoupling economic growth from natural resources exploitation [2]. The EU Green Deal poses a challenge for the Union, where the economic development paradigm pursued so far has shown its main criticalities from the environmental perspective: overexploitation of natural resources, emissions and pollution, economic disparities, and social inequalities. The policy efforts deployed in the last decades have not addressed them successfully, given that territorial, social, and economic disparities persist [19] (if not widening in some cases). Then, the EU transition opens a window of opportunity to intervene for achieving sustainability and resilience from a multidimensional perspective. In this direction, the digital transition results are important if opportunely targeted to support the ecological one. Given their difference in nature, dynamics, and characteristics, it is extremely difficult to align them (ecological and digital) [25]. Instead, the aim is to exploit innovation and technological advancements to address environmental challenges, boost circular economic development, and support forms of social innovation and interactions between citizens, public, and private actors for a more inclusive society. Such an integrated approach finds in cities the ideal place to deploy possible innovative solutions [26, 27], and urban policies and planning can support such a transformative development.

Following this rationale, the book focuses on a better understanding of ESs in urban environments. It delves into the policy and practical aspects of ESs in cities and highlights the transformative potential of their integration into urban planning and design.

The first thematic area explores the role of ESs for and from the planning dimension, focusing on data-driven approaches. Cities today must innovate to thrive, and integrating ESs into urban planning can drive innovation. By leveraging interdisciplinary knowledge, cities can develop solutions that enhance sustainability and livability, addressing ecological and human needs. Cities and urban areas can be designed and managed to support ecological functions and provide multiple benefits to residents by improving green infrastructures, which are critical factors in innovative urban planning practices.

Indeed, green infrastructure and ESs are pivotal in fostering ecological transitions within cities and can contribute to creating resilient, adaptable, and ecologically sound cities. In this direction, the evolutionary nature of urban planning can contribute to address the challenges the challenges and opportunities of the transition.

The second thematic area covered by the book relates to data-driven approaches, frameworks, and methodologies for measuring ESs. It reflects the rising relevance of exploiting innovative technologies and approaches in our daily lives and elaborating innovative solutions to the challenges ahead. Such a also emerges in the urban planning field—and process—where the combination of interdisciplinary linkages between urban and territorial studies with computational science contributes to the development of innovative approaches and methods to better comprehend social, economic, and environmental phenomena and developing innovative approach in supporting decision-making and urban planning. Measuring ESs through data-driven approaches for urban planning is relevant for several reasons. Firstly, it provides vital information on the status and health of our natural capital, helping identify the level of natural ecosystem degradation and its ability to produce ESs. Obtaining precise and reliable information through data-driven approaches could enhance sustainability by helping to balance ecological, economic, and social goals. Moreover, by understanding the value of ESs, urban planners can effectively integrate natural capital into planning processes promoting sustainable development. This helps ensure that urban development does not come at the expense of environmental health and that cities can continue to provide essential services like clean air and water, climate regulation, and recreational spaces. Moreover, data-driven approaches in measuring ESs can support resilience and adaptation efforts. With climate change increasing the frequency and severity of extreme weather events, it is crucial to design urban areas that can withstand and recover from these impacts. By measuring ESs, planners can identify and enhance natural capital that provides critical buffering and adaptive functions, such as wetlands for flood control or urban green areas and forests for heat mitigation through green infrastructure design. Various methodologies for spatializing ESs and assessing their economic, social, and environmental benefits are exposed, providing a foundation for their inclusion in policy and planning. They emphasize the relevance of sustainability indicators as powerful tools for guiding urban development to implement green strategies, ensuring that urban growth aligns with ecological objectives. Moreover, such methods emphasize the importance of embracing an Adaptive Urban Planning perspective in facing rapid urban change and the potential of Big Data and Urban Informatics for Planning the Transition of Cities, delving into how these technologies can be harnessed to measure and manage ESs, facilitating the transition to more sustainable cities. At the same time, such thematic area inquiries also in the social dimension of the transition, addressing the socio-economic dimensions of urban ecological transitions in terms of green certifications and initiatives that can inadvertently contribute to spatial inequalities, highlighting the need for equitable planning approaches.

In conclusion, this book invites readers to explore the transformative potential of ecological and digital transitions in urban environments, offering practical insights and strategies for creating sustainable, resilient, and equitable cities.

The research projects at the core of contributions presented in this book represent an innovative effort to advance urban and territorial planning discourse and practice in the face of climate change. By integrating biodiversity, key enabling technologies, and inclusive economies, these projects offer a holistic and forward-looking approach essential for navigating contemporary urban challenges. The outcomes of these endeavors are poised to influence academic research, policy formulation, and urban planning practices, with the overarching goal of creating cities and territories that are sustainable, resilient, inclusive, and responsive to the evolving needs of diverse communities.

The contributions collected for this book have been presented at the International Symposium "Networks Markets and People - Communities, Institutions and Enterprises towards post-humanism epistemologies and AI challenges", scheduled from May 22–24, 2024, in Reggio Calabria, Italy, in the specific thematic sessions "Ecological And Digital Transition In Cities: Measuring Ecosystem Services For Urban Planning And Design", as part of the research activities conducted within three Next Generation EU-funded research projects (Pilot Project 4.6.1 – Goal 4.6 – Tech4You Innovation Ecosystems; ECO-SET—A Multidisciplinary approach to plan Ecosystem Services for cities in Transition; PLANET—PLANning Ecosystem services for cities in Transition). The conference saw the participation of high-quality international academics and experts from an international network of higher academic institutions by guesting significant contributions to stimulate a fruitful debate on global challenges among academics and policymakers. The themes discussed in these sessions followed the critical elements of the debate on a shift in policy design and implementation to drive transition-oriented structural changes in regions and cities. In this direction, this book offers the chance to navigate the complexity of transition and resilience by outlining possible policy agenda priorities, new approaches, cases, and experiences that enrich the flourishing academic and policymakers debate on the green and digital transition.

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Contents

Urban Planning, Design, and Governance Environment for Urban Transformations Enhancing Ecosystem Services

Ecosystem Services Innovation and Integration of Knowledge for the Contemporary City

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Abstract. The territory, today, is very vulnerable and unprepared for possible changes linked to the uncontrolled exploitation of resources which causes land consumption. Cities increasingly suffer impacts, often catastrophic, because they have to deal with climate change. Contemporary urban planning is therefore urged to search for new paradigms more suited to the scenario of malaise in which we live. Specifically, the role of the evaluation of Ecosystem Services (ES) is of particular importance as a cognitive and interpretative support for the different functions of the soil, directly connected to human well-being and their value for the quality of life. Furthermore, the potential of environmental infrastructures as a tool for structuring a widespread and sustainable project for cities is fundamental, capable of enhancing the different vocations of the urban environment, starting from the conservation and enhancement of the ecosystem functions that the soil provides. The paper highlights the importance of the function of valorising ES as a possible response to the needs of the contemporary city, through new scientific methodologies, which offer a possible approach to the prevention of ecological problems caused by human action, and to the resolution of conflicts arising from changes in land use.

Keywords: Ecosystem Services · Innovation · Contemporary City

1 Ecosystem Services and the Contemporary City

Introduction

The cities of the third millennium must deal with epochal changes: those linked to climate, pollution, land consumption and energy consumption, attempting to increase the ability of the urban environment to deal with the effects of these changes.

Land consumption has made cities more fragile in the face of the devastating effects of climate change. A paradigm shift is therefore necessary. Territorial planning must protect the soil and related ecosystem services (ES); it must also promote the recovery and restoration of those soil functions which in the urban context can help implement innovative ES integration strategies in favor of and in response to climate adaptation.

All soil ES are important, and in the urban environment some are particularly important, such as those that can increase resilience to climate change. Awareness has grown on issues such as the fight against land consumption and urban regeneration. The effects

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of climate change make it increasingly clear that the urban development model implemented to date is no longer sustainable. On the one hand, we need to plan to prevent a further worsening of the impacts of these effects on urban centers by limiting land consumption. On the other hand, at the same time, we must act to implement all the corrective measures necessary to mitigate these effects.

The functionality of ecosystems and the interactions that man develops with them can determine the overcoming of these difficulties and problems. This innovative approach to urban planning represents a possible and valid response to the increasingly widespread and worrying soil sealing, which is the main cause of the loss of biodiversity and the destruction of both rural and natural landscapes.

In this sense, if the evaluation and mapping of ES, providing qualitative knowledge of the soil's functionality, can direct the transformations of the territory from a perspective of ecological sustainability, on the other hand environmental infrastructures constitute a methodological approach to urban planning, currently at the center of the main Italian and international landscape and territorial planning experiences, which addresses the project of urban and peri-urban open spaces, in a trans-scalar perspective, with the aim on the one hand of enhancing existing ES and on the other of create, through NBS (Nature-Based Solutions) interventions, an urban structure that is resilient and adaptive to environmental pressures and more generally to climate change, in which the provision of natural spaces also provides a possible response to conditions of safe use of open spaces urban even in situations of new emergencies.

1.1 The Urban Ecosystem

In the seventies of the last century, following the studies on natural ecosystems initiated by the IBP (International Biological Programme)[1], later replaced by the Man and Biosphere program[2], scholars realized that they had to also consider man as part of the ecosystem calculation. of nature, and its main user and modifier. The main innovation was precisely that of considering the city as an *ecosystem*, that is, characterized by a constant flow of incoming and outgoing matter and energy. The city, therefore, considered as an ecosystem, but with the difference that a natural ecosystem is capable of self-feeding with a final budget in balance while the city lives *«crossed by a flow of materials, of atmospheric gases, of water, means of transport, people, and expels, like any living organism, the waste of its metabolism towards the air, rivers, sea, soil, the urban environment itself and its inhabitants, towards the surrounding environments»*[3].

The urban ecosystem[4] can therefore be assimilated to a highly complex system, which depends on the levels of anthropization and social and technological development to satisfy the needs of the population. The city, therefore, is not only the place where human beings coexist, but it is a complex ecosystem, which arises from man's need to fit in, as a social animal, in an environment (the urban one) made up of equally complex, between people, between people and nature and between people and cities. Paul Crutzen,

[1] https://www.nasonline.org/about-nas/history/archives/collections/ibp-1964-1974-1.html.
[2] https://www.mase.gov.it/pagina/il-programma-uomo-E-biosfera-mab.
[3] G. Nebbia, 2006.
[4] M. Nicoletti,1978.

Dutch Nobel Prize winner, defines this era as the "Anthropocene"[5] to underline that it is Homo Sapiens who play a main role in every ecosystem on this planet.

Therefore a new era, characterized mainly by the action of man, which has effects not only on the atmosphere and climate, but on all the cyclical processes of transformation of the planet.

Here, the cities of the third millennium must, therefore, deal with epochal changes caused mainly by human action: those linked to climate, pollution, land consumption and energy consumption, and therefore find themselves having to attempt to increase the capacity of the urban environment to deal with the effects caused by these changes. Starting from land consumption, which has made cities more fragile in the face of the disastrous effects of climate change. Soil is a precious and non-renewable resource: consumption and waterproofing lead to the loss of the numerous ES that the soil offers.

Planning for climate adaptation and the protection and restoration of soil and related ES are closely related. Together with urban planning standards and urban greenery, ES are considered structuring elements for the contemporary city due to their benefits which do not exclusively concern the large or global scale, but also the local one, as they act positively on the well-being of the community and the public health. ES are provided by natural soils and are often compared, in the contemporary Italian debate, with urban planning standards, *but "they depend on the complexity relationships that develop in the organization of ecological variables and cannot be standardized in an undifferentiated parameter"*[6].

1.2 The Functions of Ecosystem Services

The concept of ES[7] is the core of the process of valorisation of natural capital and a "strong" reason for the conservation of nature and biodiversity. In systemic terms, these services can be considered as flows provided by stocks of natural capital, and a large part of them are indispensable for the life of man and nature itself.

The National Biodiversity Strategy for 2030 is based on the vision that *"Biodiversity and ecosystem services, our natural capital, are conserved, evaluated and, as far as possible, restored, for their intrinsic value and so that they can continue to sustain sustainable economic prosperity and human well-being despite the profound changes taking place at global and local levels"*[8].

In fact, the large quantity and variety of functions and SEs that the soil has are specifically ecological functions that have a direct and indirect benefit for humans, in close relation with the conditions of the animal and plant communities that support them.

The concept of ES has been subject to different and often contradictory definitions and interpretations: sometimes it is used to describe the internal functioning of the

[5] Crutzen, P.J. (2005)

[6] C. Giaimo, (2019).

[7] The expression SE was introduced for the first time by Robert Costanza in 1997: Ecosystem services consist of flow of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare.

[8] https://www.mase.gov.it/sites/default/files/archivio/allegati/biodiversita/strategia_nazionale_biodiversita_2030.pdf.

ecosystem (energy flows, interactions of the food network) and sometimes it refers to the benefits deriving from ecosystem processes at man (food production). According to the definition given by the Millenium Ecosystem Assessment, ES are those *"multiple benefits provided by ecosystems to mankind"*. These services, therefore, have a close relationship with the well-being conditions of the community.

The current conditions of global warming, the increase in heat islands, the risk of flooding and more have sent a serious alarm to all those skills that deal with the territory, its maintenance, and its transformations. The current territory is vulnerable and unprepared for possible changes, also due to uncontrolled land consumption. It is therefore the cities that suffer impacts, often catastrophic. The urbanization processes that have occurred in recent decades have generated a series of negative impacts on the environmental balance of the territories, resulting in the irreversible transformation of permeable natural surfaces, compromising the ecological functions of the soils and the loss of their important ES with important environmental and socio-economic impacts for the community. On an urban and peri-urban scale, the progressive infrastructure of the territory has produced the fragmentation of natural capital and the reduction of large areas of naturalness. The report "*Land consumption in Italy 2023",* published by ISPRA[9], confirms that land consumption, which has reached a speed of 2.4 square meters per second, has advanced, in just twelve months, by another 77 km^2: over 10% more than in 2021. This consumption had not slowed down even in 2020, despite the months of blocking activities during the lockdown.

Land consumption, therefore, generates the loss of a plurality of precious ES. To understand the importance of soil and its role in maintaining a balanced and healthy ecosystem, it is necessary to know what its ES are (i.e. the processes through which natural ecosystems satisfy the needs of human beings and contribute to their well-being); know what the peculiar characteristics of the soil are in the environment in which you live or work, and also have information on the technical and scientific tools that can be put in place to safeguard it in quantity and quality. In addition to air and water, natural capital is also made up of soil and its specific characteristics and qualities. These specific characteristics are the basis of a series of processes - cycle of nutritional elements, water cycle, biological activity, structure formation, gas exchange - through which the soil is able to carry out very important functions such as the regulation of the microclimate, the sequestration of carbon, the creation of a water reservoir, the supply of raw materials, food and fibre, and thus contribute to providing "ecosystem services"[10]. The functions that the soil performs, and the connected ES, vary in space, in relation to the characteristics of the soil, and in time, in relation to the conditions (climatic, management, etc.) of the context. In fact, different soils provide different services and/or of different quality. In an urban area, the most important ES are the regulation ones which recall the theme of sustainability and urban metabolism: the energy that is managed within the ecosystem

[9] https://www.snpambiente.it/snpa/consumo-di-suolo-dinamiche-territoriali-E-servizi-ecosistemici-edizione-2023/.

[10] Ecosystem services are divided into 4 categories: 1) support life, because they host plants, animals and human activities; 2) supply, because they produce biomass and raw materials; 3) regulation of hydrological and bio-geochemical cycles; 4) cultural values, as a historical-archaeological archive and a fundamental part of the landscape.

engine is returned to a level that can be used by the engine of the nearby ecosystem. The notion of ES is closely linked to the concepts of sustainable planning, green strategies, and Nature-Based Solutions (NBS). Indeed, economic prosperity and well-being strictly depend on the state of the natural resources that surround us, the so-called natural capital, and on the ecosystems that provide essential goods and services.

To preserve natural resources and ES, the help of green infrastructures is used. Urban green space is a component of green infrastructure and consists of a service that cities provide to citizens to promote their well-being. The most common definition of urban green space was given by the *European Urban Atlas* which considers urban green areas as public green areas used mainly for recreational purposes, such as gardens, parks, suburban natural areas and forests, or green areas bordering urban areas managed and used for recreational purposes.

According to the definition given by the European Union, green infrastructure is a strategically planned network of natural and semi-natural areas with other environmental elements, designed and managed to provide a wide range of ES.

Among the different types of urban green spaces, it is possible to recognize a variety of natural spaces: large and small, public, and private, simple, and complex, which when combined form a green network (for example, natural open spaces, river areas, forests, parks, gardens, squares, vegetable gardens, rows of trees, urban greenery, ponds, green roofs and green walls).

This includes green spaces and other physical elements present on land or in the sea.

Among the green infrastructures on land, we have rural and urban ones which include the Natura 2000 network, parks, gardens, hedges, vegetated strips, artificial elements such as hanging gardens, green walls, ecological bridges[11]. From an ecological-environmental point of view, green infrastructures reduce the fragmentation of natural habitats, increase the degree of biological diversity, increase self-regenerative capacities, reduce the ecological footprint of cities, mitigate the effects of climate change, reduce the effect of heat island present in the city. Furthermore, they support the spread of cycle and pedestrian mobility, fuel short-chain agriculture, improve liveability and recreational activities.

In general, it is possible to categorize the benefits produced by green areas as *environmental*: improvement of air pollution and the urban heat island effect; *social*: natural features can play an important role in residents' sense of belonging to the community and through interaction; *health*: individuals living in areas with a shortage of green spaces may be more vulnerable to stress. In fact, as a positive consequence, there has been a reduction in the number of hospital admissions caused by cardio-respiratory diseases; physical: one of the main determinants of physical activity is access to green spaces.

Today, the main reference that establishes the principles of sustainable development, the 2030 Agenda, with its 17 Sustainable Development Goals (SDGs), establishes common objectives that the member states of the United Nations are committed to achieving. Objective 11 *Sustainable cities and communities* is specifically designed to describe the

[11] Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Review of progress made in implementing the EU green infrastructure strategy - Brussels, 24.5.2019 COM.

strategies to be implemented to make cities and human settlements inclusive, safe, long-lasting, and sustainable. However, the implementation of interventions that contribute to the construction of *urban green infrastructures* can bring numerous positive effects, which go beyond Objective 11 alone, therefore contributing to the achievement of other objectives among those envisaged by the 2030 Agenda, as they are capable of ensure: *environmental benefits*, provision of clean water, removal of pollutants from air and water, improved pollination, protection against soil erosion, increased pest control, improved soil quality*; benefits of climate change adaptation and mitigation,* flood mitigation, strengthening ecosystem resilience, carbon storage and sequestration, mitigation of the effects of urban heat islands, prevention of disasters due to extreme events; *biodiversity benefits*, improved wildlife habitats, ecological corridors, landscape permeability; *social benefits*, better human health and well-being, job creation, diversification of the local economy, more attractive and more liveable cities, integrated transport and energy solutions, better tourism and leisure opportunities.

From the recent debate on ES it emerges that they have great potential as an interpretative tool at the service of planning; their functions make clear society's dependence on natural resources and their substantial irreplaceability. Furthermore, the debate on ES focuses on the recognition of the socio-ecological value of natural components; on the involvement of a plurality of subjects; on the need for a holistic interpretation of the man-nature relationship. ES constitute a central theme for the development of good planning practices aimed at introducing regenerative solutions to urban systems.

To plan first and act later, it is therefore useful to know the characteristics of the soil of a specific territory and the relative quantity and quality of ES. A paradigm shift is therefore necessary. Territorial planning must protect the soil and its ES; it must also promote the recovery and restoration of those soil functions which in the urban context can help authorities to implement innovative strategies for integrating ES into urban development and regeneration in response to climate adaptation. Starting from the soil, which is the non-renewable resource par excellence, therefore, the most effective actions on the adaptive capacity of urban systems concern the management of natural capital, and require tools and solutions that use urban greenery, soil permeability, rainwater management and sustainable mobility.

But how can this change be counteracted? Contemporary urban planning is urged to search for new paradigms more suited to the scenario of malaise in which we live. The first strategic axis concerns "mitigation", measures aimed at reducing greenhouse gas emissions, a type of intervention that concerns the production, mobility, energy and land use sectors, i.e. those most responsible for the increase of emissions. The second axis concerns "adaptation", a strategy to be implemented in a preventive or reactive way, to reduce the extent of damage.

2 Integration of Knowledge for the Spatial Analysis of Functions

The *evaluation* and *mapping* of Ecosystem Services are scientific methodologies that offer an approach to the prevention of ecological problems caused by human action and the resolution of conflicts resulting from changes in land use. The approaches for the spatial analysis of the functions of these services use specific indicators. These are no different from other environmental indicators, but they focus on the environment in a different way: in addition to biophysical data, they try to capture how this information can be interpreted with respect to the benefits of nature for humans. This implies that ES indicators are often composite indicators, i.e. they combine various measurements of the supply and use of a benefit provided by an ecosystem.

The attempt to integrate the concept of ES into policies and decision-making processes has guided scientific research in the identification of increasingly developed and complex methods to evaluate and monitor these services in space and time with the aid of technological innovations, to example in the field of remote sensing and big data. The evaluation of ES is carried out by means of quantitative indicators, which constitute a simplification of complex biophysical, social and economic phenomena[12]. To map an indicator, it is necessary to acquire a series of information, which must be subjected to a *harmonization process,* in terms of scale and precision. The same indicator can vary significantly depending on the seasonality and the unit of representation of the information. The operational methodologies using software allow you to analyze large quantities of data easily and quickly. The methodology for processing the data concerns the ability to *produce spatialization of biophysical values* which makes it possible to make explicit the ability of a soil to perform or not perform ecosystem functions in such a way that all this intercepts the urban planning project. ES are synergistic, each one can help the other to make the system work and it is therefore important to understand the needs and functions of a specific urban and territorial structure.

From the 1970s onwards, the land has been occupied, without understanding how it works, most suited to the balance of the system. Here, then, this approach serves to reverse this trend, that is, to ensure that the natural capital needed to have a good quality of life (air, water, soil, etc.), is not used improperly within of the urban ecosystem.

To date, there are a range of methods and technologies (integrated modeling, open data, etc.) that demonstrate the momentum of research in attempting to quantify and monitor the natural capital and ES from which society benefits, with the aim of improving understanding of socio-ecological systems. Progress has been made with the development of tools (web platforms) that use artificial intelligence systems or that employ technologies, such as *machine reasoning and machine learning,* to model problems and phenomena of a socio-economic and environmental nature, such as capital mapping natural and ES. These platforms use an approach in which data and models are annotated as concepts and processed by artificial intelligence, to produce new knowledge and encourage its sharing and dissemination.

To obtain a more accurate quantification of the ES supply, models and software are often used, based on changes in land use and land cover, such as ARIES (ARtificial Intelligence for Ecosystem Services), InVEST (Integrated Valuation of Environmental Services and Tradeoffs) and SOLVES (Social Values for Ecosystem Services). ARIES is an open-source tool that allows you to encode ecological and socioeconomic data to map the supply, use and flows of ES using geographic information systems (GIS). The INVEST software includes fifteen models that analyze different processes that occur in terrestrial and marine ecosystems, and which are the basis for the estimation of ES, while SOLVES is a functional tool for evaluating, mapping and quantifying the perceived

[12] B. Burkhard, & J. Maes, 2017; B. Burkhard, M. Kandziora, Y. Hou, & F. Müller (2014).

social values of ES, such as aesthetics and recreation. I-Tree is another famous tool for quantifying the benefits and values produced by trees and can also be used at smaller scales (roads, plots, etc.). I-Tree provides several tools to evaluate specific benefits at different scales[13].

In a broader sense, scientific research and related technological innovations are called to guide the transition of growth and development models traditionally focused on economic performance, towards an integrated approach between ecology and economy, oriented towards the well-being of individuals and social sustainability, economic and environmental.

From a planning point of view, there are practices, which are increasingly consolidated, for strengthening resilience and adaptation objectives. There is now a wide range of technical solutions and implemented interventions that are part of NBS, which can carry out decisive tasks to increase resilience, and of establishing "adaptation solutions" on the territory through urban infrastructures. It is necessary, therefore, to plan and design for *objectives and requirements*: the ES are not new urban planning standards, but they are a new approach, a new paradigm capable of addressing the planning of cities for objectives, having in mind the awareness of which requirements can and should be asked of urban infrastructures. From an operational point of view, this means integrating traditional urban planning regulations with settlement structure rules that highlight areas of the city equipped with ecological-environmental standards in such a way as to pursue, for each urban regeneration intervention, the maintenance and valorisation of those indispensable ES in the urban context. It is therefore necessary to make this type of ES approach effective by integrating it into the vast phenomenology of data, information and variables that distinguish the process analysis-evaluation-project in planning activity.

Having recognized the emergence of a new 'urban question', the topic of soil today poses new and broader questions aimed at limiting its consumption and redefining its design contents. It is therefore on the awareness of having to harmonize the maintenance - or reconstitution - of *natural capital* and the compatibility of the *fixed capital* of settlement and infrastructural systems within new practices, that the growing interest and commitment towards the theme of ES is contextualized. Qualitative knowledge related to ES appears essential for the preliminary assessment of environmental effects- and the consequent economic and social impacts - which derive from the possible land use arrangements. By estimating the ecosystem value differentials both in quantitative and qualitative terms, managing to evaluate the quality rather than just the quantity of transformed soil: an evaluation that offers useful knowledge to support choices, policies and projects for ecologically oriented, urban and territorial regeneration support of urban planning choices that take into account the containment of land consumption and the protection of its ecosystem functions.

[13] Marino D., Poli D., Rovai M. (cura di) 2022.

3 Concluding Considerations

In conclusion, it is possible to formulate some general considerations useful for summarizing the concepts presented so far. It is necessary for all the actors involved in the planning process to understand in a profound and coherent way the critical issues and possibilities they are facing. The containment of land consumption, the difficult reproducibility of some environmental units and their respective ES, the need to operate environmental mitigation and compensation where a transformation involves a worsening of environmental quality, constitute some of the numerous pieces that make up the mosaic of sustainable urban planning.

Cities as complex ecological systems constitute the main place of exploitation of ES and at the same time the privileged environment from which to start again to implement resource management that is proactive and directed by targeted policies.

These reflections underline, therefore, the importance of incorporating multiple perspectives in the evaluation of ES, capable of considering the different dimensions of value in the study of ES to support *decision makers* in defining actions aimed at increasing the quality of life in cities. Biophysical, ecological, and economic values have been widely studied, but there are critical issues in the evaluation of intangible values, such as sociocultural ones, and in the integrated consideration of all dimensions of value. Indeed, a pluralistic vision of ES research has become more important than ever, especially when it becomes a tool to support the planning and transformation of cities in a sustainable way. The proposed methodological approach considers not only the biophysical and ecological value provided by ES, but also their translation into economic terms, integrated with values of a sociocultural nature.

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Author Index

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