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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 Restoration 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 nowadays 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 aim to promote economic and social inclusion and catalyze environmental sustainability. Urban regeneration shows the potential to address global challenges and support the local ecological, 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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Measuring the Value of Ecosystem Services

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Abstract. Although the literature on the valuation of ecosystem services is becoming substantial, with an increase in the number of scientific articles over the last thirty years, it still lacks a widely accepted methodology for mapping and measuring the value of ecosystem services that is suitable for defining a strategy for their spatial planning and management. Measuring the value of ecosystem services requires, in fact, the coordination of multiple, composite and, quite often, conflicting dimensions of value. It is an articulated process, as the valuation of each ecosystem service requires scientific expertise in different fields that must, however, interact with each other, as well as a wealth of data whose availability and accessibility varies in terms of accuracy, updating, size scale, etc. Moreover, while for the assessment of some ecosystem services, well-established methodologies are available, for others, assessment techniques are still being tested. This paper - which summarises part of the work carried out during the first year of the Pilot Project “Climate adaptation plans for the reduction of the ecological footprint and ecological debt aimed at improving the conservation” within the SPOKE 4 (executor) “Resilience and accessibility in the valorisation of local cultural and natural heritage” (for a Budget of PP 2.2 million Euro) of the TECH4YOU Research Project “Technologies for climate change adaptation and quality of life improvement”. PNRR-funded project - explores the main theories and experiences in this field.

Keywords: Ecosystem Services · Assessment Methods · Indicators and Mapping

1 Foreword

This paper summarises some of the work carried out during the first year of Goal 4.6 “Climate change planning to promote cultural and natural heritage: Demand-driven ecosystem services based on ICT and AI enabling technologies”, and of the Pilot Project “Climate adaptation plans for the reduction of the ecological footprint and ecological debt aimed at improving the conservation” within SPOKE 4 (executor) “Resilience and accessibility in the enhancement of local cultural and natural heritage” (for a PP Budget 2.2 million Euro) of the TECH4YOU Research Project “Technologies for climate change adaptation and quality of life improvement”. Project financed PNRR mission 4, component 2 investment 1.5 - Innovation Systems 2 - ranked 1st, at national level, for proposal quality.

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In particular, it refers to a specific segment of Action 1 - Green and blue infrastructures as mitigation and offset ecosystem services, namely that aimed at defining the measurement of the value of ecosystem services.

1.1 Ecosystem Services

Ecosystem services can be defined, in a very general way, as the services provided by nature that are necessary for the sustenance of human beings and the societies of which they are part. The concept of ecosystem services originated in the scientific literature of the 1970s and spread from the 1990s onwards with the aim of giving economic weight to the contribution that ecological processes make to human well-being. To the traditional strand of the study of ecosystem services concerning the territory and related to natural ecosystems has recently been added that of urban ecosystem services, which is related to Urban Ecology, the latter generally defined as a sub-discipline of ecology. This approach, which has emerged fairly recently, has its roots in studies conducted since the 1920s in the United States and after World War II in Europe, but emerges as a discipline mainly at the end of the 20th century, with contributions such as Bolund & Hunhammar's article, 'Ecosystem services in urban areas'. (1999).

Over the last two decades, ecosystem services have therefore been the subject of in-depth conceptual and methodological analysis and evaluation models that have been continually refined, including the territorial representation of these services and the quantification of their value, both monetary and otherwise, up to the introduction of Payment for Ecosystem Services (PES) mechanisms.

This report provides, without claiming to be exhaustive, an overview of the classification and approaches aimed at their analysis and evaluation, including their cartographic restitution.

In particular, we consider the dimension of territorialisation of ecosystem services with associated qualitative or even quantitative attribution, in the second case not necessarily economic, to be used above all, but not only, as a tool for defining effective mitigation and compensation measures and launching virtuous policies for the construction of green and blue infrastructures and urban and territorial regeneration.

With regard to the valuation of ecosystem services, which will be dealt with in more detail below, it is noted that the recognised methods are both monetary (these include market methods, for example of greenhouse gases, but also exchange methods, such as PES) and non-monetary, in the second case with the objective of representing quantity and quality not expressed in money but in such a way as to make the different values evident; among the latter methods are also socio-cultural ones.

The concept of ecosystem services took off, in parallel with Urban Ecology (a discipline for the study of urban ecosystems), in the 1980s, and the first publication containing this term, according to the majority of studies on the subject, was entitled 'Extinction: the Causes and Consequences of the Disappearance of Species' (1981), by the American biologists Paul R. Ehrlich and Anne H. Ehrlich.

With the studies by Robert Costanza (1997) and Gretchen C. Daily (1997) began the dissemination of this concept, which was consolidated with the essays of Rudolf S. De Groot (2002), the Millennium Ecosystem Assessment (MEA 2005) and the TEEB Report (2010).

The scientific literature and the documents produced provide different definitions and classifications of ecosystem services, although they are anchored to a rather clear conceptualisation and linked to an approach that puts the human being at the centre; in other words, the dynamics of ecosystems are read in function of the satisfaction of human needs. Several conceptual schemes are proposed through which to represent, in a synthetic and structured manner, ecosystem services and to relate ecosystem functions to goods and ecosystem services themselves, and thus, ecosystems to socio-economic systems.

2 Ecosystem Service Assessment Methods

Although the literature concerning the valuation of ecosystem services is becoming substantial, with an increase in the number of scientific articles since 1997 - the year of publication of the work of Robert Costanza who was among the first to bring this issue to the forefront - there is still a lack of a widely accepted methodology aimed at mapping and measuring the value of ecosystem services that is suitable for defining a strategy for their spatial planning and management.

Measuring the value of ecosystem services requires, in fact, the coordination of multiple, composite and, quite often, conflicting dimensions of value. It is an articulated process, as the valuation of each ecosystem service requires scientific expertise in different fields that must, however, interact with each other, as well as a wealth of data whose availability and accessibility varies in terms of accuracy, updating, size scale, etc.

Moreover, while for the assessment of some ecosystem services, fairly well-established methodologies are available, for others, assessment techniques are still being tested.

In Italy, for example, the studies conducted are rather limited, and almost always circumscribed in terms of the extent of the area considered and the number of ecosystem services examined. Measuring the value of ecosystem services, in fact, is a fairly recent line of research (Santolini R., 2008). And, specifically, it seems to lack an exhaustive and in-depth definition of the various ecosystem services at the most detailed scales, such as regional and urban, which would instead be of great use to be able to direct planning and management strategies towards more conscious choices for a sustainable use of resources. (Santolini R., Morri E., 2017a; Santolini R., Morri E., 2017b). On the other hand, it is correct to point out that the assessment of ecosystem services is not a simple and quite costly operation, particularly due to the unavailability of suitable and up-to-date databases at the various scales of intervention.

To date, the mapping and valuation of ecosystem service provision hinges mainly on literature studies and modelling methods. Among these, the main ones concern: the market valuation method (Bateman et al. 2002; de Groot et al. 2010), ecological process simulation (Nedkov, 2012; Stürck et al. 2014), InVEST models (Arcidiacono et al. 2015; Boithias et al. 2014). Also of great interest for our research is the methodological approach based on land cover (Burkhard et al. 2015; Burkhard et al. 2009; Burkhard et al. 2012). The latter method, which is widely used, consists of quantitatively assessing the ecosystem service provisioning capacity of different land cover types.

2.1 Assessing Ecosystem Services Through the Economic Approach

The public good character of most ecosystem services means that, very often, they do not have an explicit economic value, which creates significant difficulties in the valuation process.

Robert Costanza, for one, points out that the methodical underestimation of the environmental issue in decision-making processes can be traced back to the fact that the goods and services provided by natural capital cannot be estimated in comparable terms with other services and other forms of capital.

It is, however, now well established that the loss of ecosystem services is a threat not only to our existence but also to our economy. Therefore, the issue is the subject of various studies and research.

In this regard, the following are some highlights from a study conducted by the Institute of Management of the Scuola Superiore Sant'Anna in Pisa on the economic valuation of ecosystem services.

Why Evaluate Ecosystem Services

- Biodiversity suffers from the effects caused by indirect factors, such as population growth, a lack of knowledge of the issues surrounding it and the fact that its economic value is not considered in decision-making processes.
- The EU biodiversity target is based on the recognition that, in addition to its intrinsic value, biodiversity and the services it provides have considerable economic value that the market rarely captures

Preserving and restoring ecosystems and their services implies that the economic value of Ecosystem Services is recognised and its valuation integrated into decision-making processes at both public and private levels.

Economic valuation helps to strengthen understanding and communication of the values of natural capital and ecosystem services.

What to evaluate

- Direct use value. Use value derives from the actual, expected or possible consumption of a good. When there is direct human use, we speak of direct use value: it is used for all provisioning services and some cultural services, e.g. recreation.
- Indirect use value. Usage can also occur indirectly, and this is the case with the benefits derived from all regulation services
- Option value. Option value falls into the category of use value, but in this case the use is not current but future. The individual does not use the good/service currently but is nevertheless willing to pay a certain amount in order to have the possibility of using that good/service in the future. The definition of option value is linked to the concept of risk aversion: since people are uncertain about the future supply of the environmental good/service, they are willing to pay a sum of money today that guarantees them the possibility of use in the future.
- Existence value. It is based on the awareness of individuals that the considered good exists and continues to exist, even if they will never use it. An individual may be willing to pay for the preservation of the Amazon rainforest even though they will never visit it, but only because they value its existence.

- Inheritance value. It derives from the fact that the person valuing is willing to pay a certain amount so that other people may enjoy the property in question.

How to evaluate

There are two different approaches to which different methodologies can be attributed:

1. Direct or ‘market price’ methods are based on measuring the value of SEs through market prices. The market, in fact, is the place where individuals reveal their preferences and willingness to pay (one speaks in this case of ‘*revealed preference*’).
2. Indirect or ‘contingent valuation’ methods involve field surveys to identify the willingness to pay for a given ecosystem service (hence ‘*stated preference*’). Many ecosystem services, however, are not traded in observable markets, and are not closely related to any marketed products. Thus, individuals cannot ‘reveal’ how much they are willing to pay through their market purchases or through their actions.

Some methods are more suitable than others for defining the value of particular ecosystem services. For example, market prices are often used to estimate provisioning services; while surveyed preferences are usually used to define non-use values. In some contexts, however, it may be convenient to use several methodologies simultaneously.

Non-market methods are more widely used, as they allow the impact of a hypothetical physical transformation of the ecosystem on the well-being of individuals to be measured; in this way they provide an ex-ante estimate, which is useful for defining possible intervention scenarios. Such methods, however, are reproached for the predominance of users’ opinions and needs over the maintenance or improvement of ecological conditions.

These two macro-categories are not, however, the only ones that can be used; in fact, there are others such as meta-analysis and value transfer, which, however, cannot be considered true economic evaluation tools, as they use data from other studies.

2.2 Assessing Ecosystem Services Through the Land Use Approach

The aforementioned approach, based on the quantitative assessment of the provisioning capacity of ecosystem services by different land cover types, is a widely used assessment methodology. In recent years, many researchers have used this method for both large- and small-scale assessments.

In this regard, the work of Burkhard et al. has been widely recognised for its advantages over other methods. It is, in fact, a fairly rapid evaluation method with clear advantages for decision-making. Furthermore, it can be applied to different spatial situations and requires little data at an early stage: land cover types and expert knowledge.

Indeed, the quality and quantity of ecosystem services are explicitly conditioned by structural and functional changes in different land cover types (ecosystems). For example, changes in land use can affect regional or global climate (Pielke, 2002) which, in turn, can lead to a decrease in the capacity of local and global climate regulating services. Additionally, improper land use can cause habitat and landscape fragmentation (Mitchell et al. 2015; Mitchell et al. 2013), the subsequent disintegration of wildlife

habitats as well as the modification of landscape connectivity. And all this can affect, directly or indirectly, the formation and provision of ecosystem services.

However, it must also be said that in some cases, the impact of land use change on ecosystem services can also be positive. For example, Lovell (2010) argues that urban agriculture is a sustainable and multifunctional land-use option for cities; Hostetler et al. (2011) assert that the creation of urban green infrastructure is crucial for the maintenance of biodiversity. Therefore, proper management and optimisation of land use patterns can ensure the maintenance and increase the genesis of new ecosystem services (de Groot et al. 2010).

2.3 Assessing the Socio-cultural Value of Ecosystem Services

People attribute different material, moral, spiritual, aesthetic and other values to the environment; their values can influence their attitudes and actions toward ecosystems and the services they provide. These values include emotional, affective and symbolic visions related to urban nature that in most cases cannot be adequately captured by commodity translates and monetary metrics. Here we refer to these values broadly as social and cultural values. The literature on ecosystem services has defined cultural values as “aesthetic, artistic values, educational, spiritual and/or scientific benefits of ecosystems” (Costanza et al. 1997) or as “non- material benefits that people gain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience” (Millennium Ecosystem Assessment, 2005).

Social and cultural values are included in all major types of ecosystem services (Daily et al. 1997; de Groot et al. 2002; Millennium Ecosystem Assessment, 2005). However, compared to economic and biophysical values, social, cultural, and other non-material values of ecosystems and biodiversity have generally been neglected in much of the literature on ecosystem services. In addition-although more recent research has made substantial progress in attempting to better integrate social perspectives and valuation techniques into the ecosystem services framework and to enable a more comprehensive representation of sociocultural values in theory and practice-social and cultural values can be difficult to measure and often require the use of approaches and methods that may include qualitative measures, constructed scales, and narratives, setting up as a kind of deliberative process involving the use of locally defined metrics.

As for the methods adopted to evaluate sociocultural ecosystem services in economic terms, there are several that measure their contribution to welfare; these fall into two categories: market and nonmarket. The former is based on real transactions and behaviors, and the latter engages users through surveys.

Market methods are in turn divided into direct and indirect.

In the former case we use the market price or production function, identifying the contribution made by the ecosystem service to another good, or the cost-based method that measures costs from production to supply.

In the second (stated preference method), reference is made to hedonic price and travel cost. Non- market methods, also called stated preference methods, are used when one intends to evaluate the impact of hypothetical changes in the ecosystem and the provision of its services. Among the most relevant are contingent valuation and choice experiments.

In addition to these two macrocategories, there are others that cannot be considered true economic evaluation tools because they use data collected from other studies: meta-analyses and value transfer. Cultural ecosystem services, for example, are almost always not monetizable, making the use of direct market valuations impossible. In some cases, it is possible to exploit indirect ones such as the cost of travel for recreational, tourism services and hedonistic pricing for aesthetic values.

Non-market methods are the most widely used because they allow the impact of a hypothetical physical transformation of the ecosystem on well-being to be measured, producing an ex-ante estimate that is useful for understanding possible scenarios and where action is needed.

The methods of the surveyed preferences are challenged, however, by the prevalence of users' opinions and needs over the maintenance or improvement of ecological conditions.

Below is an illustration of the main features of the different methods.

Indirect market methods

When cultural ecosystem services are not tradable, it is, in fact, necessary to use indirect market methods to measure the implicit price, through that of a good traded in the market.

Hedonistic valuation makes it possible to identify the impact that certain environmental conditions or ecosystem services have on the price of a good.

The large number of data needed, the risk of omitting important variables, and the willingness to pay for a specific area are the critical issues in this mode.

The cost of travel is another example. Typically used for tourist and recreational sites, it allows for estimating the value associated with their cultural ecosystem services. The expenses incurred for travel, including time, cost of transportation and access, reveal the willingness to pay to take advantage of specific services.

To be effective, a multiplicity of respondent information and surveys conducted at different times and seasons are required. Processing is done through statistical analysis and complex models. The difficulty to be addressed is the measurement of actual time spent, made greater in cases where the site to be visited is not the sole objective of the trip.

Non-market methods

Nonmarket methods are based on direct consumer surveys. Contingent valuation is constructed from the questionnaire that asks people how much they are willing to pay to maintain a certain ecosystem benefit and how much they would accept in return for giving it up.

Analysts must calculate the average willingness to pay and willingness to accept of respondents and multiply that value by the amount of people using the resource, thus estimating the total economic value attributed.

The construction of the survey is based on a six-step process:

1. definition of the problem to be evaluated and the hypothetical target market, selecting the ES and mechanisms to be used.
2. sample definition, deciding how many and which users to involve.

3. development of the basic structure of the questionnaire, choosing the appropriate form depending on the context and needs of the research.
4. identification of people's level of knowledge with respect to the asset, allows questions to be formulated and useful information to be presented appropriately.
5. Implementation of the questionnaire.
6. Analysis of results and estimation of mean value.

The process is suitable in any situation and can estimate both use and nonuse value.

The choice experiments method is based on the assumption that each good can be described in terms of characteristics and attributes. It asks respondents to indicate preference among several alternatives, allowing users to report in a simple and intuitive way the value they assign to benefits. It is developed in three main steps:

7. problem definition;
8. survey design;
9. Statistical analysis of data.

Other methods

Meta-analysis allows the synthesis and analysis of available empirical evidence on a given topic. Comparing and combining economic evaluations from different research allows for better estimates and to detect the factors that determine their variations. It also allows for generalization of results. Having identified the relevant literature, the data collected and the characteristics of the studies are coded and entered into a database. The accuracy of the results depends on the availability of the data and the statistical techniques through which they are processed.

Value transfer employs, at the site under analysis, economic assessments previously conducted in a similar area. It involves a simple approach or the use of value functions. The first approach is based on univariate transfer; averages of values from one site to another are reported directly. The second approach from the reference data constructs value functions for the site under consideration. Errors may occur in the original site estimate, during the transfer from one site to another, or in the calculation of the total economic value, compromising the results of the study.

3 The Evaluation Process According to MAES: Ecosystems, Indicators and Mapping

In this section, we will take as our main reference the Reports produced by MAES in the period 2013–2018, which are fundamental for the understanding and choice of the method to be applied for the elaboration of the Ecosystem Services assessment matrices.

The MAES is a working group established in 2012 by the European Commission, with the extended name of Mapping and Assessment of the Ecosystem and their Services, which has set itself the objective of supporting and increasing the mapping of ecosystems and their services for the European territory.

Within this project, four interim reports on specific aspects were published (2013, 2014, 2016a, 2016b) and the final report was published in 2018 by the European Union. In addition, a specific report on soil ecosystems was published in 2018.

In the first report ‘Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020’, from 2013, highlights the fact that mapping and analysis of ecosystems and ecosystem services is one of the key points of the EU Biodiversity Strategy.

In that document, it is noted that biodiversity plays a key role in the structural definition of ecosystems that are essential for maintaining basic ecosystem processes and sustaining ecosystem functions, the latter being defined as the capacity or potential to provide ecosystem services. Ecosystem services derive from ecosystem functions and through these goods and benefits are produced for humans; for this reason, ecosystem services are subject to economic valuation, although not all of them can be measured in monetary terms.

With reference to the latter, the importance of including other types of assessments, such as those on health, social conditions or conservation aspects, is highlighted. The report also states that healthy ecosystems (in good condition) have a full potential for ecosystem functions (consequently, ecosystem services) that are supported by biodiversity, for which the various aspects that contribute to ecosystem functioning are defined and which, in some cases, directly determine ecosystem services.

The second report, ‘Mapping and Assessment of Ecosystems and their Services - Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020’, from 2014, provides a list of reference indicators for measuring ecosystem services at the national scale. These indicators are defined for the three ecosystem services (provisioning, regulating and maintaining, cultural) and for each of the main ecosystems, i.e. forests, agro-ecosystems (crops and grasslands), running and still waters (lakes, rivers, groundwater and wetlands), marine and transitional areas.

The third report, ‘Mapping and Assessment of Ecosystems and their Services - Mapping and assessing the condition of Europe’s ecosystems: Progress and challenges’, from 2016, concerns the mapping and analysis of ecosystems.

The fourth report, ‘Mapping and Assessment of Ecosystems and their Services - Urban ecosystems’, also published in 2016, addresses the topic of mapping and analysis of urban ecosystems (defined as socio-ecological systems that are composed of green infrastructure, understood as networks of urban green spaces, and built infrastructure) and proposes indicators to assess their conditions as well as that of urban ecosystem services.

This document is intended to support European policies concerning urban areas, represented by the EU Urban Agenda (2015), the EU Biodiversity Strategy (2011), the Green Infrastructure Strategy and Nature-based solutions (NBS).

Several case studies of European cities are presented in the report, including examples of the identification of urban ecosystems and/or ecosystem services and their representative indicators and mapping.

The fifth report, ‘Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition’, from 2018, identifies indicators for mapping and assessing the condition of ecosystems at the European level.

In particular, it provides a set of specific indicators for the assessment of ecosystem conditions for each ecosystem type, as well as a core set with key indicators to support an integrated ecosystem assessment per ecosystem type.

3.1 Classification of Ecosystems

With regard to the classification of ecosystems, the aforementioned fifth report, 'Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition', classifies ecosystems by correlating them with land uses and grouping them into six macro-families, which are described as follows

1. *Urban Ecosystems*

An urban ecosystem is the ecological system located within a city. Like any other ecosystem, urban ecosystems are composed of interacting physical and biological components. Consequently, indicators measuring the condition of urban ecosystems and the pressures acting on them concern both the built and green infrastructure that together constitute cities.

2. *Agroecosystems*

Agricultural land use is the main land use in the European Union and accounts for 45% of its total area. The type of ecosystem addressed in this section is agroecosystems, understood as communities of plants and animals that interact with their physical and chemical environment and have been modified by humans to produce food, fibre, fuel and other products for human consumption and processing.

3. *Forests and Woodlands*

Forests and woodlands cover about 40 per cent of the EU's land area and are home to much of Europe's biodiversity. Similarly, forests provide multiple ecosystem services that support and satisfy human needs. As a result, society benefits from forest services and at the same time modifies forest ecosystems through a range of direct and indirect pressures, e.g. land use, climate change, air pollution and invasive alien species contribute to shaping the condition of forests.

4. *Natural Ecosystems (Heaths and Shrublands, Sparsely Vegetated Land and Wetlands)*

This section focuses on ecosystems that are largely covered by the Habitats Directive (HD) and the Birds Directive (BD), the so-called Nature Directives because of their high biodiversity values. According to the MAES typology, these ecosystems are "Heaths and Shrublands", "Sparsely Vegetated Land" and "Wetlands".

5. *Freshwater Ecosystems*

Freshwater ecosystems include rivers, lakes and groundwater. Their condition and functioning are closely linked to natural ecosystems at the water-land interface, such as riparian areas, floodplains and wetlands. This section of land use types focuses on rivers, lakes and groundwater, while wetlands are covered in Sect. 4 and transitional and coastal waters in Sect. 6.

6. *Marine Ecosystems*

This section focuses on marine ecosystems, defined as encompassing all marine waters, including those at the land/sea interface with salinities above 0.5‰. Following the MAES typology, four ecosystems are considered: marine inlets and transitional waters, coastal waters, shelf waters and the open ocean.

3.2 Ecosystem Service Indicators

The report also identifies, in illustrative tables, the soil ecosystem services related to the three main categories, identifying the appropriate processes required to produce

these services, and provides, again in tables, for each ecosystem service, indicating the relationship with the CICES classes and types, a list of related indicators, for which the reference spatial dimension (regional or local) of application is defined, the nature: supply or use services, and the availability of data.

The document also describes indicators for the assessment of pressures and soil ecosystem conditions. With regard to pressures, reference is made to: agricultural land management intensity; forest management intensity; soil sealing; soil disturbance; land use change; soil moisture; contaminated sites; gross nutrient balance; water extraction; organic matter loss; soil erosion. Soil ecosystem conditions refer to: soil erosion; soil sealing; soil contamination; water supply capacity; soil nutrient concentration; soil organic carbon; soil moisture; bulk density; soil biodiversity.

The document also contains a summary of the impacts that each pressure causes on biodiversity in relation to different ecosystems (urban, agricultural, grassland, forest, shrub, wetland, inland aquatic, marine). The pressures considered are the following: habitat modification, climate change, overexploitation, invasive alien species, pollutants and nutrient surplus.

The assessment of impacts is represented with classes referring to intensity (low, moderate, high, very high) and with indications of expected trends (decrease, maintenance, increase, very rapid increase).

3.3 Mapping Ecosystem Services

Ecosystem services, due to their peculiarities, are localised in specific areas and it is therefore possible to map them spatially; several studies have highlighted how they can be considered “spatially specific” (Boyd and Banzhaf, 2006) or “spatially explicit” (Haase et al. 2014) and this is the characteristic that makes them a non-tradeable and non-saleable good. With regard to these considerations, it is noted that ecosystem services refer to a particular spatio-temporal dimension, in the sense that they can be used in place but also in distant places, as some of them (e.g. water for drinking) can be formed in a particular place and period but be used in other places in later periods.

The forms of mapping and representation, as well as the methods of evaluation, vary and, to some extent, depend on multiple factors, such as: the objective of the analysis, the spatial scale of restitution, the information available, the level of depth of the investigation, the resources that can be used and the tools - especially IT tools - available. There are numerous studies and proposals in this regard (Burkhard and Maes, 2017; Crossman et al. 2013; Hauck et al. 2013; Martínez-Harms and Balvanera, 2012) and there is no single shared procedural model, although the indications of the MAES project advocate the use of models capable of ensuring, at the very least, the scientific accuracy, reproducibility of the methods and reliability of the analyses produced (scientific accuracy, reproducibility, credibility).

The mapping, considering the two main forms of restitution suggested by the 2016 MAES report, can represent the supply or provision of ecosystem services (supply), which is indispensable for making assessments, or the demand of the population. The latter must be such as to allow cross-referencing with the former, both in order to verify the territorial coincidence or otherwise with supply and to direct spatial and urban planning; this in view of the fact that land-use transformations decisively condition the

supply of ecosystem services and that, therefore, appropriate choices of urban plans and projects can ensure its preservation or enhancement.

In fact, the mapping of ecosystem services, combined with the representation of their value (qualitative or quantitative, not necessarily monetary), has a strong communicative potential towards decision-makers and towards local actors and the non-expert population. In this regard, it should be noted that for the construction of the maps, particularly those of demand, it may be appropriate to follow paths of involvement of the various actors, who will certainly be able to provide their input with regard to expectations and needs, but also to criticalities, due to the absence or lack of services, and priorities for action.

Another relevant aspect is the choice of ecosystem services to be considered for mapping purposes. These may vary in number and typology, depending on the characteristics and size of the territorial context to be analysed and also on the final purpose; in general, the selection should be conducted by taking as a reference the ecosystem services already identified in schemes recognised at European level and taking into account the aggregation of services into the main categories (supply, regulation, cultural and, for some schemes, habitat), so that all of them can be represented.

In this regard, with regard to the different level of depth when mapping ecosystem services, some considerations from the MAES Reports are echoed.

In the second MAES report, 'Mapping and Assessment of Ecosystems and their Services - Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020', from 2014, the topic of mapping ecosystem services is considered and three levels of depth and representation are outlined.

At the first level, representing a proxy of a given ecosystem service, restitution is based on the use of indicators that can be explicitly derived from land use and land cover (e.g. Corine Land Cover) or biodiversity monitoring or forest inventory. The document emphasises that some of the indicators defined by MAES are areal elements or, in any case, spatially permeable and can, therefore, be used to construct maps.

At a second level, there is the use of a set of indicators to be composed of each other so that ecosystem services can be assessed; in this case, land use data are combined with information that takes into account the relationship between uses and ecosystem services and allows quantitative measurement for different locations or aggregations at different scales.

The third level requires the use of biophysical process modelling in a GIS environment or other software capable of cross-referencing information from several indicators. In this case, open-access programmes such as InVEST and ARIES can be used.

In the third MAES Report, 'Mapping and Assessment of Ecosystems and their Services - Mapping and assessing the condition of Europe's ecosystems: Progress and challenges' (2016), the mapping of ecosystem services is defined as the identification and delineation of the spatial extent of different ecosystems through the spatial integration of a wide range of data on land/sea cover and environmental characteristics. It defines ecosystem services capacity mapping as the combination of ecosystem maps with data on the conditions or relationships between conditions, functions and capacities of ecosystem services.

With regard to the ecosystems to be mapped, the types identified are the following: urban, agricultural-cultivated, grassland, forest, shrub and dryland, sparse vegetation, wetland, river and lake, marine inlet and transitional waters, coastal, marine shelf, and open ocean. The document provides a correlation table between MAES level 2 and level 1 or 2 of the EUNIS habitat classification system, which in turn can be associated with the Corine Land Cover categories.

Regarding modalities, the report points out that several methods can be used to map the supply of ecosystem services. These range from the use of indicators such as carbon storage capacity, crop yield or water infiltration into the soil (Layke et al. 2012), to the method based on expert opinion on the performance of different types of land cover to generate specific services, to that using process models. The paper notes that indicators for mapping the supply of ecosystem services have already been developed, citing for example authors Burkhard et al. (2012), Haines-Young et al. (2012).

With regard to the methods of cartographic restitution of ecosystem services at a territorial scale, some significant experiences are recalled.

In the article by B. Burkhard et al. from 2009, an initial study phase is proposed and defined as suitable for the development of integrated strategies for the provision of ecosystem services at territorial level.

This phase is based on the analysis of Corine Land Cover data that allow for the expert assessment of the different potential of different land covers to provide ecosystem services and, therefore, for their restitution by means of cartographic representations; the authors emphasise that, in particular, the spatial explication of information obtained through mapping has a high potential in favouring the understanding of complex and interacting systems (Dresner, 2008).

For the elaboration of the maps, a matrix is developed, through which the different capacities of land cover classes to provide ecosystem services are identified; in detail, the 44 Corine Land Cover classes are crossed with the 29 ecosystem services selected by taking into consideration the lists proposed by De Groot (2006), the Millennium Ecosystem Assessment (2005) and Costanza et al. (1997), as well as the list on the integrity of ecological components described by Müller and Burkhard (2007). Each crossroad is assigned a rating class defined according to the following capacity scale: 0 = not relevant; 1 = not very relevant; 2 = relevant; 3 = medium relevance; 4 = high relevance; 5 = very high relevance.

The allocation of these classes is based on an initial expert assessment and feedback from different case studies. It can be tested by applying it to other cases - with additions, modifications and adaptations - in relation to available information and models from expert estimates, as well as by assessing the importance of particular ecosystem services in the territorial contexts analysed.

The methodology was applied in the case study of the Halle-Leipzig area, a region in the central-eastern part of Germany, within the framework of the PLUREL project; in this case study, two maps were produced to restore the spatial distribution of ecosystem services, as of 1990 and 2000, in order to be able to make a comparison and to verify and highlight the changes resulting from changes in land cover.

Another application, at a more recent date, was carried out in the Baltic geographical area and the results are described in the publication edited by Kalvane I., Burkhard B.,

Ruskule A., Bojars E., “Methodological Guidelines for Mapping and Assessment of Grassland Ecosystem Service”, Baltic Environmental Forum - Latvia (2014).

This document provides guidance for the mapping of ecosystem services and their assessment at the local level. In the introduction, it is noted that the quality of ecosystem service mapping studies depends on the methods used to quantify and map, the information available and the purpose of use.

The study applies the crossing matrix between the Corine Land Cover categories and the selected ecosystem services, with each crossing assigned a relevance value from 0 (absent) to 5 (highest).

This procedure is based on expert estimation, biophysical quantification and the result of empirical modelling, estimating the capacity to provide ecosystem services that are attributed to land use or land cover classes.

The paper points out that for more complex analyses, GIS processing models are available for the assessment of ecosystem services, and briefly recalls and describes those that are most widely applied, namely InVEST, ARIES and SolVES.

4 The Valuation of Ecosystem Services Within the Teach4You Research Project “Technologies for Adapting to Climate Change and Improving Quality of Life”.

On the basis of the above, in the context of the Teach4You Research Project “Technologies for adapting to climate change and improving quality of life”, it was decided to refer to the method of estimating the capacity to provide Ecosystem Services in relation to different types of land use.

The classes of Ecosystem Services considered are those based on the lists proposed by: Costanza et al. (1997), de Groot et al. (2002), Millennium Assessment (2005) and de Groot (2006). In these lists, Ecosystem Services are grouped into four main categories: regulatory services, provisioning services, habitat services and cultural services.

With regard to the land use classes considered - grouped according to the six macro categories proposed by MAES and outlined above - these refer to the Copernicus database.

The Copernicus Land Monitoring Service (CLMS) provides geographical information on land cover and related changes, land use, vegetation status, water cycle and land surface energy variables. It enables applications in various sectors such as urban and spatial planning, forest management, water management, agriculture and food security, conservation and restoration of the natural environment, rural development, ecosystem accounting and climate change mitigation/adaptation.

In particular, as far as it is of research interest, the land monitoring service offered by Copernicus covers:

- Information on land cover and land cover change in European countries over the period 2000–2018.

This information on land use types and their spatialization is taken from the CORINE Land Cover programme. The CORINE programme was initiated in the European Union in 1985 (EEA, 1994) and the database includes 44 land cover classes

in Europe. The Corine Land Cover (CLC) project was created specifically to survey and monitor land cover and land use characteristics, with particular attention to environmental protection requirements. The initiative, co-financed by the Member States and the European Commission, was joined in 2000 by 33 countries, including Italy, where the National Authority for managing the project was identified in APAT, as the national focal point of the European EIONet network.

- Information on land cover and land cover change in European cities in the period 2012–2018.

This information on land use types in urban areas and their spatialization is taken from the Urban Atlas programme. The Urban Atlas (UA) dataset provides land cover/land use data on Functional Urban Areas (FUAs). The main datasets are: Urban Atlas 2006, Urban Atlas 2012, Urban Atlas 2018, the change datasets 2006–2012 and 2012–2018 and the Street Tree Layer 2012 and Street Tree Layer 2018 products. At the European level, the 2006 dataset includes 319 FUAs representing areas with more than 100,000 inhabitants, the 2012 dataset includes 785 FUAs with more than 50,000 inhabitants, and the 2018 dataset consists of 788 FUAs.

From the production of the 2012 dataset onwards, the nomenclature identifies 17 urban classes with a minimum map unit of 0.25 ha and 10 rural classes with a minimum map unit of 1 ha. The update frequency is six years.

5 Conclusions

In closing this brief discussion, it is worth pointing out how the assessment of ecosystem services is a crucial element in the planning process of territories and cities, especially from a point of view that places at the center the creation of a different scientific and cultural approach that contributes to creating a collective knowledge and awareness of the real value that they assume in future development choices aimed at guaranteeing human wellbeing, since they constitute an inseparable and bidirectional link between man and ecological systems.

Designing according to nature-based solutions may, in fact, constitute an innovative way, as it is based on a vision that places nature at the center of transformation choices, also through the identification of alternative scenarios that are both efficient and economically appropriate.

Evaluating ecosystem services becomes, therefore, a basic action to prepare design scenarios for cities and territories by estimating ex ante policies, projects and realization of works, and works and, furthermore, to be able to measure the level of wellbeing of the population and prefigure possible future evolutions, providing decision-makers with the tools to mitigate the possible effects of actions that could affect wellbeing and quality of life.

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