Urban Ecosystem Services: A Review of Definitions and Classifications for the Identification of Future Research Perspectives

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Abstract. Thanks to many initiatives, such as the Millennium Ecosystem Assessment (MEA), The Economics of Ecosystems and Biodiversity (TEEB) and EU target for 2020 on Biodiversity, the topic of ecosystem services has received even more attention both in the academic and political debate. On the contrary, the research on urban ecosystems and urban ecosystem services has yet been relatively modest compared to other ecosystems, like wetlands or forests. However, the relevance of topic requires more efforts in this field also because, in most cases, urban ecosystem services have been studied individually, without considering their role in governance and planning processes. In this context, the present paper has the aim at giving a perspective of the state of the art of the research on urban ecosystem services with a focus on the different definitions and classifications emerging from the literature, as well as of examples of indicators for their valuation. The work highlights the gaps in the research to support the definition of future research perspectives and analysis, in particular for the adoption of valuation approaches able to guide the decision-making process in urban areas and for ensuring the consideration of urban ecosystem services in spatial planning policies and actions.

Keywords: Ecosystem services · Land-use planning · Decision-making · Evaluation methods · Resilient city

1 Introduction

Why should we talk about ecosystem services and urban ecosystem services in cities?

As it is well known, cities worldwide are responsible for more than 70% of energy-related emissions and United Nations predict that by 2050 over 70% of the world population will live in urban areas [1]. In particular, in the EU, almost three out of four citizens still live in cities and the number will further grow [2].

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All these people need an inclusive, healthy, resilient, safe and sustainable living environment [3–5]. As a consequence, demands on natural capital and ecosystems services is going to increase steadily in our urbanized planet [6–8].

However, the way of how to achieve these challenges is not completely clear. As pointed by Gómez-Baggethun and Burton [9], the research on urban ecosystem services still represents an open frontier in the wider context of ecosystem services researches, even if many studies have been conducted over the years on their role and importance. Just think that very recent researches have been funded by the EU – i.e. the Mapping and Assessment of Ecosystems and their Services (MAES) [3] and the EnRoute project [10] – which are pilot project mainly focused on the role of urban ecosystems and urban ecosystem services. These two contributions are closely related and in line with the EU target for 2020 on Biodiversity [11], which requires the restoration and maintenance of ecosystems and related services through an increase in knowledge of ecosystems, promoting the use of green infrastructure and reducing the loss of biodiversity and services.

As Gómez-Baggethun and Burton [9] pointed, cities, as any other social-ecological system, depend on ecosystems and their components to sustain long-term conditions for life [12], health [13, 14], security [15], good social relations [16] and other important aspects of human well-being [9, 17]. Cities depend on ecosystems beyond the limits of the city itself, but also benefit from urban ecosystems within the city [18].

In this context, the paper aims at developing a perspective of the state of the art of the research in the context of urban ecosystem services with a focus on the different definitions and classifications emerging from the literature. In this way, it is possible to start from the very baseline context in order to support the definition of future research perspectives and analysis, in particular for the adoption of valuation approaches able to guide the decision-making process in urban areas for ensuring the consideration of urban ecosystem services in spatial planning policies and actions.

2 Literature Review and First Insights

The approach used in this research was based on a review of main scientific publications on the topic of urban ecosystem services, including quantitative and qualitative content analyses. The review considers only scientific articles published in English from the Scopus database with the aim at highlighting the main trends of the research in this context, but in particular to give a more comprehensive view on the definitions of urban ecosystem services in literature for guiding future challenges of the research in this field. The analysis and collection of papers were performed between October 2019 and February 2020. The result is a number equal to 2,747 documents by limiting the search to title, abstract and keywords, using the string search (TITLE-ABS-KEY (“ecosystem services” AND (cities OR city OR “urban areas” OR “urban area”)) AND (LIMIT-TO (LANGUAGE, “English”))). The string considers both the term urban areas and cities, even if the two have a different meaning, in particular in the context of ES valuation, as we discussed in detail in the next section. This is a precautionary choice to avoid losing documents related to the valuation of ecosystem services at the city scale which represent the point of view of this research more than at the territorial one.

As it is possible to see in Fig. 1, the research on urban ecosystem services started around 1995, but the first main relevant publication on this topic is in 1999 the work by Bolund and Hunhammar [18]. Then, we have to wait until 2005 for a number of publications per year greater than 10, and 2011 for an increase in the number of documents that overcomes a hundred. These two moments of breakthroughs in the literature production are not incidental, because they exactly correspond to the two major initiatives in the field of ecosystem services, which are the Millennium Ecosystem Assessment (MEA) [19] and The Economics of Ecosystems and Biodiversity (TEEB) [17]. These studies, within the research project URBES (Urban Biodiversity and Ecosystem Services) [20] developed from 2012 to 2015 and the CICES (Common International Classification of Ecosystem Services) [21] proposed in 2009, have led to an increasing interest in the academic and ever more attention in the political debate on ecosystem services, as shown by the Management Plan - Environment DG of 2012 [22].

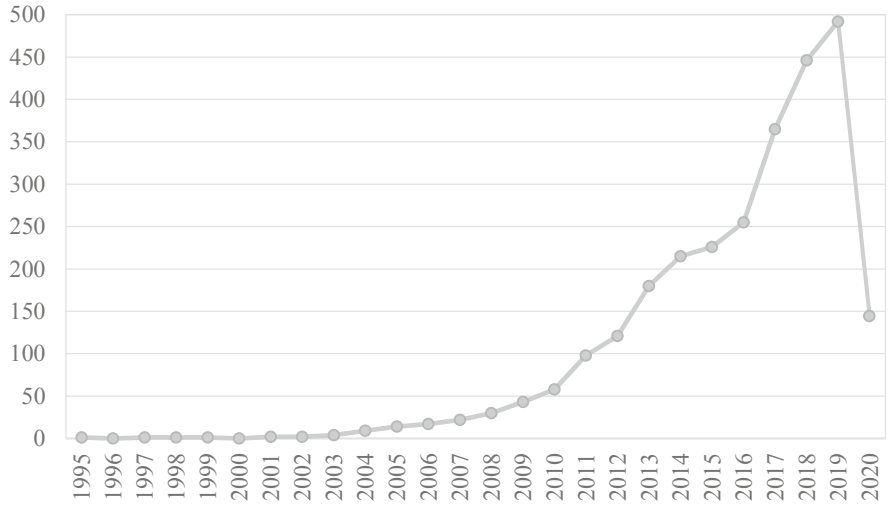


Fig. 1. Urban ecosystem services publications over the years (Scopus database)

From the literature review, it is possible to underline that the attention on ecosystem services in urban contexts is lower than the one at territorial scale, as also testified by the work of Assennato et al. [23]. Urban soils are very often perceived as a resource that can be freely managed to meet citizens' needs [24]. Moreover, compared to other ecosystems, like wetlands or forests, the focus on urban ecosystems has yet been relatively modest [9] and, in most cases, they have been studied individually. The same result is also evidence from the Luederitz et al. [25] peer-review, that shows how intensive is the literature on forests and wetlands (but also rivers and lakes) compared to street greenery, parks or green-roofs (see in particular [25] p. 105). The analysis of single ecosystem services is also demonstrated by the recent reviews on ecosystem services in urban areas, such as the work of Lundy and Wade [26] on water, the research of Wang et al. [27] on the indoor environment, the review of Salmond et al. [28] on ecosystems services and disservices provided by street trees or the research of Perrotti and Stremke [29] on the

benefits provided by green infrastructure, in particular for a more energy-efficient and less carbon-intensive urban metabolism.

The analysis of single ecosystem services is combined, in the majority of cases, with the consideration only of the economic value dimension. Monetary values have been extensively examined in the literature, while the description or measurement of symbolic, cultural, identity and other non-economic values remains largely unexplored [9, 30–32].

An exception in this context is the extensive literature review developed by Luederitz et al. [25] which tries to bridge the gap analyzing the different perspectives to be considered in urban ecosystem services research. Due to the inherently complex and interdisciplinary nature of ecosystem services analysis [33], it is necessary to cover the wide range of perspectives from which such research can be conceptualized and undertaken. The challenges concern the achievement not only of ecological modelling and economic assessment but also issues such as governance, planning and stakeholder involvement [25].

A change of course is, therefore, necessary for this field. If the ecological studies have covered most of the attention in the literature, the governance aspects represent the less considered, as it emerges from Luederitz review [25]. This is tremendously problematic since without proper institutional and organizational structures or policy instruments is quite difficult to achieve the performances required, to control decision-making process in planning and to manage the course of actions of transformations in urban contexts.

3 Classifications and Definitions Emerging from the Literature

Starting from the wider considerations emerging from the previous analysis of the literature, this section has the aim to highlight the different classifications and definitions on the topic of urban ecosystem services. The literature review shows two main different classifications provided by Bolund and Hunhammar in 1999 [18] and Baggethun et al. [9], instead an in-depth analysis on research groups and European projects on urban ecosystem services adds to the previous classifications, other two interesting ones (SUITMAs group and, MAES and EnRoute projects). These four are presented and extensively analyzed in this paper.

However, to better clarify what we mean when talking about urban ecosystem services, it is necessary to take a step back illustrating the single meanings of "urban" "ecosystem" and "ecosystem services". Starting from "ecosystem", it can be defined as "a set of interacting species and their local, non-biological environment functioning together to sustain life" [34]. For the "urban" environment, it is possible to define the city as a single ecosystem or a set of different individual ecosystems which compose it, such as green areas or rivers [18, 35]. "Ecosystem services" are, then, defined by De Groot et al. [36] and the Millennium Ecosystem Assessment (MEA) [19] as benefits that humans obtain from ecosystem functions, whereas Costanza [37] and The Economics of Ecosystems and Biodiversity (TEEB) [17] as direct and indirect contributions from ecosystems to human well-being. Or even, following Daily et al. [33] "ecosystem services" are the conditions and processes through which the natural ecosystems - and the species that compose such systems - support and satisfy human life allowing the conceptualization and management of the relationship and interactions between men and

environment in the wider context of sustainability. All these definitions highlight the relevant degree of interdependence between humans and the rest of nature [38].

The meaning of "urban ecosystem services" is strongly based on the previous definitions by simply restricting the area of interest. In fact, if ecosystems - both inside and outside urban areas - are often modified to provide specific ecosystem services to inhabitants [39], "urban ecosystem services" are those services that are directly produced by ecological structures within urban areas or peri-urban regions.

If there is essentially a shared vision on the definitions of all these terms and concepts, the analysis of the literature shows a less clear perspective in term of classifications of urban ecosystem services. This could be explained for different reasons. Firstly, the researches have started, of course, from different moments of history in the analysis of ecosystem services. As an example, the first paper of Bolund and Huhammar [18] is strongly based on the work of Costanza [37], instead, the work of Gómez-Baggethun and Burton [9] was based on the classifications emerging from MEA [19] and TEEB [17] (and the work of Dobbs et al. [40]). Secondly, and probably more important, it is the fact that the limit between urban and non-urban, and so, between ecosystem services and urban ecosystem services, is often blurred and not easily delineated. As a consequence, it is not that surprising that different perspectives exist and the two definitions (ecosystem services and urban ecosystem services) increasingly tend to converge.

Figure 2 illustrates schematically the literature considered in this paper for understanding the different classifications of urban ecosystem services, with also the connection with the previous works from which they are derived. The authors themselves specify in their contributions the previous references used for conducting their research on urban ecosystem services.

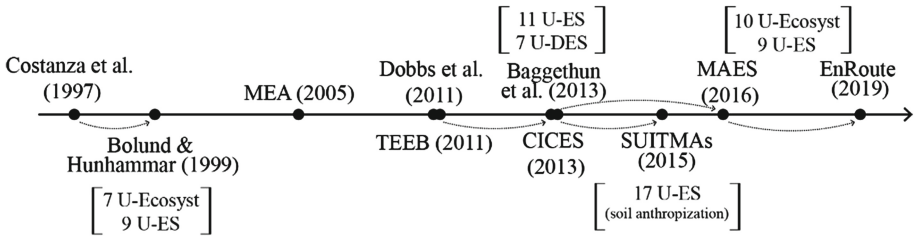


Fig. 2. Timeline framework of urban ecosystem services classification

First Classification. The first classification on urban ecosystem services was performed by Bolund and Hunhammar in 1999 [18]. As mentioned before, this paper represents one of the first attempts and without no doubt the first most relevant contribution on this topic. For the identification of the ecosystem services related to the urban context, the authors started from the 17 ecosystem services defined by Costanza et al. [37]. In particular, Bolund and Hunhammar [18] identified 7 urban ecosystems (trees, lawns/parks, urban forests, cultivated land, wetlands, lakes/sea, and streams) and 9 related urban ecosystem

services (air filtering, micro-climate regulation, noise reduction, rainwater drainage, sewage treatment, recreational and cultural values, food production and erosion control).

Second Classification. Gómez-Baggethun and Barton [9] proposed an alternative classification. Starting from the previous categorizations of ecosystem services [19, 33, 36] and in particular from the 22 ecosystem services defined by TEEB (2010) [17], the authors used the same four categories (provisioning, regulating, habitat, and cultural and amenity services), identifying 11 ecosystem services and 7 examples of disservices for the urban context. In particular, these services are especially important in the urban context, as they provide a direct impact on health and security. The services considered are:

- for provisioning: food supply
- for regulating: water flow regulation and runoff mitigation, urban temperature regulation, noise reduction, air purification, moderation of environmental extremes, waste treatment, climate regulation, pollination and seed dispersal
- for cultural: recreation and cognitive development
- for supporting: animal sighting (habitat for biodiversity).

Instead, the examples of disservices reported are air quality problems, view blockage, allergies, accidents, fear and stress, damages on infrastructure, habitat competition with humans.

Apart from the different number of urban ecosystem services considered, the two works differ in the final objective of the research. The first classification comes from a more site-specific analysis, where Stockholm is taken as an exemplary case study for analyzing this topic. In fact, Bolund and Hunhammar [18] clearly underline how some services (in particular food production and erosion control) should not be considered for the specific area under analysis. This local perspective could have, in some way, limited the selection of different services. On the contrary, the second work has the aim to provide a more global perspective on this theme, considering both European and non-European case studies and literature references for identifying a list as comprehensive as possible.

Third Classification. More in line with the second classification, it is the work of SUITMAs (Soil of urban, industrial, traffic, mining and military areas), a research group founded in 1998 to promote soil science in heavily populated areas [24]. In this case, the focus is more on the assessment of the ecosystem services in urban contexts than on the identification of a list of services. However, it is interesting to notice that compared to the previous classification, this one considers a greater number of services, 16 against 11 of Bolund & Hunhammar [18], following the CICES classification [21]:

- for provisioning: food production, non-food biomass, reservoir of minerals, freshwater supply;
- for regulating: water storage, runoff and flood control, pollution attenuation, global climate, local climate, biodiversity, invasive species, air purification, noise control;
- for cultural: recreation/tourism, archives of human history, landscape, education.

The relevant aspect of this classification, however, is related to how the urban ecosystem services are evaluated. The evaluation is based on the level of the anthropization of the soils. More details on this aspect are given in the next chapter of the paper.

Fourth Classification. The last (and more recent) classification considered in this paper is the one from the EU project MAES (Mapping and Assessment of Ecosystems and their Services Urban ecosystems) [3] and EnRoute project (Enhancing Resilience of Urban Ecosystems through Green Infrastructure) [10]. The first one is mainly focused on the identification of the list of urban ecosystem services, through different methodological steps:

1. a preliminary list of ecosystem services emerging from the analysis of the literature and an online questionnaire with different stakeholders on the measurement and policies related to urban ecosystem services;
2. an additional contribution of researchers and stakeholders on real examples mapping and assessment of ecosystem services based on some European cities;
3. interactive discussions on the content of step 1 and 2;
4. synthesis and reporting phase.

The final result of these steps is a set of indicators for measuring the following urban ecosystem services:

– for provisioning: food supply, water production
– for regulating: air purification, climate change regulation (reduction of CO2), temperature regulation, noise mitigation, water flow regulation and runoff mitigation, insect pollination
– for cultural: recreation, education

The second project, the EnRoute project [10], started from the work of MAES [3], intending to test the applicability of the framework of indicators identified in the previous research. In particular, the work consisted in testing, in different EU cities, the role of six policies for spreading and maintaining urban ecosystem services, with a particular focus on mapping and evaluating urban green infrastructures and related actions.

It is important to notice that interesting reflections have been emerged from the EnRoute project [10], in particular for what concerns the definition of a proper scale for studying urban ecosystem services. In fact, as mentioned before, one of the main criticalities and difficulties when referring to urban ecosystem services is setting the boundaries for evaluating the benefits and impacts of such services, as well as also the boundaries of what is urban and what is not. The project underlined for each indicator the proper scale of measurement, distinguishing between core city and functional urban area. This second scale is specifically defined during the EnRoute project [10], as a specific operational spatial extension able to takes into account the city and its surroundings, in a view of the interdependence of cities and external landscape, constituting an urban ecosystem in itself.

4 Discussion

The previous paragraph has shown the different classifications emerging from the analysis of the literature. This section, instead, has the aim of providing a guide for the evaluation of the different urban ecosystem services resulting from the previous investigations. Moreover, starting from this list, it is possible to give some suggestions for future perspectives and key challenges for the research.

Table 1 reports the list of urban ecosystem services provided by the authors of the paper considered. For each class, it is reported the main reference from which these services derived, and the indication of the urban ecosystem considered in the classification of each author. This table gives a preliminary framework for valuating in a comprehensive way urban ecosystem services also by connecting them to the more general ecosystem services framework at the territorial scale provided over the time by Costanza et al. 1997, TEEB [17] and CICES [21].

The analysis of the literature shows a quite homogeneous way to evaluate such urban ecosystem services, strongly focused on the measurement of ecological and biophysical values of those services. A different approach is found in the third classification where the quantification of the urban ecosystem services is based on the potential of each soil category, which can be arranged according to a gradient of anthropization and the capability to support vegetation [24]. The categorization is based on 4 different groups ranging from soils with little changes compared to the corresponding natural soils - i.e., the pseudo-natural SUITMAs, often covered by urban forest or urban and suburban agriculture, to extremely modified soils usually not considered as soils by many scientists - i.e. sealed soils by SUITMAs - [24]. Intermediate categorizations are dumping site SUITMAs - sporadically re-vegetated - and engineered SUITMAs - deliberately vegetated - [24]. However, also in this case, the ecological and biophysical perspective is dominant.

Another difference emerging from this research comparison, it is the attempt of the EnRoute project in implementing and testing different actions and policies in specific cities in order to verify their effect and suitability. Even if such measures are limited to the enhancement of green infrastructure, it is a step forward for increasing the awareness of the importance of this topic in the governance of cities.

In fact, the connections between ecosystem processes and functions and human well-being are complex and the valuation of benefits and impacts of ecosystem services require to adopt a pluralistic approach [38]. Different values of ecosystem services may be captured and measured to inform urban and transformation planning [9]: ecological and biophysical elements, economic and insurance values, social and cultural aspects [17, 41]. However, if biophysical and economic values are widely experimented and studied in the literature (as also showed in Table 1), more efforts are needed for measuring socio-cultural values. This happens because emotional and symbolic values are cannot be adequately captured by common metaphors or monetary metrics [42, 43], making the assessment more complicated. It is for that reason, as underlined by Saarikoski et al. [44], that recent trends of the literature highlight the necessity to adopt alternative approaches for evaluating ecosystem services, such as multicriteria analysis (MCDA). MCDA, in general, perform better than monetary valuation in many aspects, such as the consideration of multiple dimensions – spanning from ecological to economic values from cultural

Table 1. Comparative table of the urban ecosystem services taxonomy considered in the literature

I		II		III		IV
Ecosystem Services	**Urban Ecosystem Services**	**Ecosystem Services**	**Urban Ecosystem Services**	**Ecosystem Services**	**Urban Ecosystem Services**	**Urban Ecosystem Services**
Costanza et al. 1997	**Bolund & Hunhammar 1999**	**TEEB (2011)**	**Gómez - Baggethun & Barton 2013**	**CICES (2013)**	**SUITMAs (2015)**	**MAES (2016), EnRoute (2019)**
Food production	x	Food	x	Biomass: - Nutrition - Materials from plants, algae, animals for agriculture	x	x
Raw materials		Raw materials		Biomass (fibres and other materials for direct use and processing)	x	
Water regulation	x	Water	x	Water: Materials (non-drinking)	x	x
Water supply				Water - nutrition (drinking)	x	x
-		Medical resources		Biomass (fibres and other materials for direct use and processing)		
-				Biomass (genetic materials from all biota)		
-				Biomass: - fibres and other materials from for direct use and processing - energy sources Mechanical energy (animal based)		
Climate regulation	x	Local climate and air quality	x x	Atmospheric composition and climate regulation	x x	x
Gas regulation	x	Carbon sequestration and storage	x	Mediation of gaseous/air flows	x x	x x
-	x		x	-	x	x
Disturbance regulation		Moderation of extreme events	x	-		
Waste treatment	x	Waste-water treatment	x	Mediation: - waste, toxics and other nuisances by biota - waste, toxics and other nuisances by ecosystems		
Nutrient cycling						
Erosion control & sediment retention	x	Erosion prevention and maintenance of soil fertility		Mediation of mass flows	x	x
Soil formation				Soil formation and composition		
Pollination		Pollination	x	Lifecycle maintenance, habitat and gene pool protection		x
Biological control		Biological control		Pest and disease control	x	
Refugia		Habitat for species	x			
Genetic resources		Maintenance of genetic diversity		Lifecycle maintenance, habitat and gene pool protection	x	
Recreation	x	Recreation and mental and physical health	x	Physical and experiential interactions	x	x
-		Tourism			x	
Cultural	x	Aesthetic appreciation and inspiration for culture, art & design		- Intellectual and representational interactions - Other cultural outputs (existence, bequest)	x	x
-		Spiritual experience and sense of place		Spiritual and/or emblematic	x	

Disservices
- air quality problems
-view blockage
- allergies
- accidents
- fear and stress
- damages on infrastructure
- habitat competition with humans

to moral aspects of a policy or management problem, and the creation of an open and transparent public debate on the pros and cons of alternative courses of action, including the distribution of gains and losses across beneficiaries of ecosystem services [44].

The importance of integrating multiple perspectives in research on urban ecosystem services is fundamental in order to improve decisions on the protection and enhancement of the environment, to monitor the impacts of interventions on human well-being, to support urban planning and design, and the determination of policies [44]. Moreover, the consideration of multiple values into decision-making processes still represent an underexplored field of research and, therefore, a very challenging perspective for assessing more comprehensively the analysis of urban ecosystem services [45].

5 Conclusion

Urban ecosystems and urban ecosystem services are becoming a fundamental topic of research, since the demand of natural capital is going to increase steadily in our urbanized planet. People who live in urban areas need an even more health, sustainable and environmental recreative living space. Moreover, ecosystem services could be used as a tool and opportunity that cities have to bringing positive changes, such as saving municipal costs, strengthening local (green) economies, improving the quality of life and ensuring livelihoods [17].

The present analysis has shown some common aspects and limits of the current literature on urban ecosystem services. As a consequence, we want to highlight the following recommendations for further research on this topic:

1. It is necessary a unique and shared classification of the ecosystem services provided by urban areas. Probably, the attempt to reduce the list of ecosystem services to be as general as possible is not the right way, but a more comprehensive lists of services and disservices could be used by cities as a checklist for describing their specific characteristics. In this way, both smaller and bigger cities can refer to the same framework, but they can tailor it to their specificities. Moreover, it is necessary to pay more attention on the scale of the intervention and the scale of the effects when urban ecosystem services are valuating.
2. A more holistic view of the research on urban ecosystem services is required, in order to consider all the interrelations between ecosystems in urban areas. This perspective can support public administrations and decision-makers in the definition of shared and complete actions in achieving higher level of ecosystem services performance.
3. A multi-aspects consideration of benefits and impacts of (urban) ecosystem services should be implemented in the research. The analysis of only biophysical and ecological aspects or the translation of benefits in monetary values is limited. There is a need to integrate in the valuation also socio-cultural aspects, through the adoption of non-monetary approaches and the co-participation of different stakeholders in the measurement of benefits of these services.
4. Public bodies and local administrators should identify a plan of actions for increasing the level of (urban) ecosystem services providing and avoiding the loss of these services through compensation measure to be implemented inside or outside the

area under transformation. This is possible only through the adoption of multi-methodological evaluation approaches able to give a rigorous description of the state-of-art and of the future implementations.

Overall, the key challenges of the future research on ecosystem services concern the interdisciplinarity, multi-dimensionality, multi-spatiality and temporality of the problem and the role that these services have and will have in the future of our cities [45]. In this context, only through the adoption of different evaluation tools and methodologies, in particular in their combination, can give the necessary 'value pluralism' perspective [9] in the study of (urban) ecosystem services, thus supporting the decision-making process in the definition of urban and territorial transformations. More insights on this theme are given in Caprioli et al. [45] and future perspectives of this research will explore the combination of ecological and economic measurement with cultural and moral aspects of a policy or management problem using the urban ecosystem services taxonomy proposed in this paper. If the consideration of ecological and economic aspects is widely explored in last years, more efforts are needed in the valuation of social and cultural aspects of (urban) ecosystem services. Multicriteria Analysis (MCDA) can represent an interesting approach for analyzing more intangible components of (urban) ecosystem service valuation, as also testified by the recent trends of the literature [44].

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