Reviewing the role of ecosystems services in the sustainability of the urban environment: A multi-country analysis

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A B S T R A C T

The urban environment is characterised by many pressures caused by population growth, transport (and its related emissions), and the damage to green areas. Yet, there is a variety of ecosystem services available in urban areas, which may be deployed to ameliorate the current problems and foster their sustainability. This paper reviews the role of ecosystem services as tools for sustainability, based on an urban setting. It also describes a series of multi-country case studies, where an assessment of their functions using a set of benefits valuation approaches such as health benefits, economic benefits, social benefits and benefits to climate resilience, are provided, along with an appraisal of their role in upkeeping the overall quality of the urban environment in the studied areas. Policy recommendations aimed at enhancing the role of ecosystem services, and fostering sustainability in the sampled sites -and beyond-are provided.

1. Introduction: defining ecosystem services

The term "ecosystem services" (ES) was first used by P.R. Ehrlich and A.H. Ehrlich in 1981 (Ehrlich and Ehrlich, 1981). The concept emerged from both the ecological and economic fields (Gómez-Baggethun et al., 2010). The notion of ecosystem functions that are beneficial, and thus somehow valuable to society, dates back to the 1960s (King, 1966; Westman, 1977). During the 1980s, the term "ecosystem services" was initially used to describe the benefits from nature (e.g. Ehrlich and Mooney, 1983). In 1997, it attracted a lot of attention with Gretchen Daily's book about nature's services (1997), an attempt to provide a valuation of the world's ES and natural capital (Costanza et al., 1997).

In 2005, the Millennium Ecosystem Assessment (MEA), launched by the United Nations, assessed the ramifications of ecosystems change for human well-being, and sought to establish a scientific basis for the actions needed to protect them (MEA, 2005a,b). ES were then defined as "the benefits people obtain from ecosystems" (MEA, 2005a,b, p. 39). The main arguments used were that, damages to ecosystem services could lead to substantial and largely irreversible losses to biodiversity. Whereas the MEA represented an ecological point of view, subsequent initiatives focused on the economic aspects of ES, such as The Economics of Ecosystems and Biodiversity project (TEEB), providing a framework for the assessment of economic benefits of biodiversity and ES (TEEB, 2008).

The MEA differentiates four kinds of ES (MEA, 2005a,b):

(i) provisioning services, including food, water, timber and fibre;
(ii) regulating services that affect climate, floods, disease, wastes and water quality;
(iii) cultural services, providing recreational, intellectual, aesthetic and spiritual benefits, and
(iv) supporting services such as soil formation, photosynthesis and nutrient cycling.

While the latter three services yield direct benefits to human beings, supporting services are necessary to ensure the delivery of those. The four main types of ecosystem services could all yield direct and indirect benefits to both human well-being, and fauna and flora alike. Additionally, both the supporting services and regulating services may play fundamental roles in ensuring the provision of other ecosystem services, acting as drivers.

The four main types of ecosystem services could all yield direct and indirect benefits to both human well-being, and fauna and flora alike. Additionally, the supporting services and regulating services may play fundamental roles in ensuring the provision of other ecosystem services, acting as drivers. It should however be stated that these frameworks have major differences when compared with the ecosystem services classification proposed by the Millennium Ecosystem Assessment. They may also negatively influence the implementation of many of the sustainable development goals (SDGs).

Despite their importance for human well-being, ecosystems and their underlying biodiversity are still not valued sufficiently (International Union for Conservation of Nature, 2018). Furthermore, the degradation of many ecosystems is disproportionately affecting the poor (TEEB, 2008). This process is making difficult to achieve a set of sustainable development goals (SDGs), especially SDG 1 (No Poverty) and SDG2 (Zero Hunger) among others.

In the industrialised world, the European Commission is pursuing efforts towards enhancing ES. For instance, the EU Biodiversity Strategy to 2020, via Target 2, requires member states to assess the value of their national ES (European Commission, 2011).

As part of the TEEB project, de Groot et al. (2012) identified the fact that, depending on the respective ecosystem considered, the total value of an ecosystem's potential services ranges from international $491 per year for an 'average' hectare of open ocean, up to international $352,915 per year for an 'average' hectare of coral reefs. Building on these data, Costanza et al. (2014) updated the global ecosystem value with USD 125 trillion for 2011. Kubiszewski et al. (2017) calculated different global future scenarios which amounted to a loss in ES value of USD 50.3 trillion ('Fortress World' scenario) or to a value gain of USD 30.7 trillion ('Great Transition' scenario) by the year 2050. To give another example of ecosystem valuation, Gallai et al. (2009) determined the annual value of bee and other insect pollination worldwide to be €153 billion, representing 9.5% of the world's agricultural production used for food in 2005. By way of contrast, if there were no pollinating insects, society would face losses between €191—€310 billion per year.

The ES concept has often been criticised, especially the valuation of ES. General critique includes the anthropocentric focus and vagueness of the concept, that it could impede general conservation and its implication that all ecosystem functions affecting humans are desirable (Schröter et al., 2014). Problems with valuation arise because most ES values are outside the market, are often non-material, and subjectively valued. There are also uncertainties about both ecosystem functions and human preferences (Barbier, 2017; Small et al., 2017; TEEB, 2008). The counterarguments are that ES are valued either explicitly or implicitly all the time (Costanza et al., 2017), and even a flawed valuation can serve to put the respective ES into public focus. Thus embedding ES into decision-making processes (Tallis and Kareiva. 2005).

There have been practical applications based on the ES concept, including compensations for soil sealing in urban planning (Tobias, 2013), the development of a tool to inform spatial marine planning (Guerry et al., 2012), as well as reviews of best practice examples (Beaumont et al., 2017). In Africa, some work has shown that with due care, for instance in respect of the services provided by watersheds and catchment ecosystems, progress can be achieved (Leal Filho et al., 2017a).

Also, payments for ES (PES) are possible, i.e. to internalise the externalities related to ES (Engel et al., 2008). To give an example, in some parts of the US, farmers are subsidised to leave fields fallow for several years, hence promoting soil formation and retention (Tallis and Kareiva, 2005).

In this introduction, it is relevant to refer to some previous studies addressing the role of ecosystem services in urban settings. For instance, Haase et al. (2014) examined the role of ecosystem services in urban landscapes, and suggested practical applications, also outlining possible governance implications. In a further work, Elmqvist et al. (2015) reviewed the benefits of restoring ecosystem services in urban areas, and identified based on data from 25 urban areas in the USA, Canada, and China, the fact that investing in ecological infrastructure in cities, and the ecological restoration and rehabilitation of ecosystems such as rivers, lakes, and woodlands occurring in urban areas, may not only be ecologically and socially desirable, but also quite often, economically advantageous, even based on the most traditional economic approaches (Elmqvist et al., 2015). Green and blue spaces in the city are often defined as green and blue infrastructure, with an important role in improving human well-being, resilience and sustainability of the city (Andersson et al., 2019), being the main pillar for identifying nature-based solutions for a proper land management for enhancing ecosystem services (Keesstra et al., 2018).

Ziter (2016) performed a quantitative review of the biodiversity—ecosystem service relationship in urban areas, identifying the fact that studies typically measure only a single service in one city, precluding assessment of ES synergies, trade-offs, and cross-city comparisons. Ziter (2016) suggests that while most studies attribute ES provision to a habitat or land-use type, studies that consider biodiversity-ES relationships are more likely to recognize a specific functional group, community, or population as the key provider of an ES.

This study aims to outline the role of assessing urban ecosystem services as a tool for sustainability. This is done by presenting the main challenges faced by a wide range of urban ecosystems located in different geographical settings (i.e. Europe and Latin America), and by jointly evaluating the services based on common criteria. This can be a useful qualitative tool for stakeholders to use to prioritise their decisions and actions in terms of easily translating scientific knowledge into ready-to-use information. In order to enable a better understanding of the connections between ecosystem services and sustainability in urban areas, this paper is structured as follows: section 2 provides an overview of ecosystem services in an urban setting. Section 3 describes the methodology used; section 4 describes and discusses the results obtained. Part 5 rounds up the paper and present the main conclusions.

2. The role of ecosystem services in an urban setting

This section describes the role of ecosystems services in an urban setting and outlines its various dimensions. In recent years, the world has experienced unprecedented urban growth: in 2019, over 55 per cent of the world's population lived in cities and that number is projected to increase to about 68 percent by 2050 (UN, 2018). This great urbanization generates an increase in environmental problems, affecting several sectors. Some of these issues are: water management and risks related to storm runoff, growing pollutant load in urban air (Pataki et al., 2006), biodiversity reduction and soil scarcity (Güneralp and Seto, 2013; Solecki and Marcotullio, 2013), decrease in plants capacity to retain pollutants and produce oxygen, and a large amount of energy consumption for buildings heating and cooling (Bonoli and Pulvirenti. 2018; Elmqvist et al., 2013). The same "heat island" effect, can be seen in urban areas where peak temperature occurs over buildings and streets and decreases to a minimum level in green urban areas, such as parks, gardens, and sub-urban rural areas (Mohajeran et al., 2017). Today, a spread of land degradation, a robust loss of arable land and a growth in drought and desertification represents current fundamental challenges and unprecedented opportunities to enhance the resilience and ecological functioning of urban ecosystems (Dunn and Heneghan, 2011; Solecki and Marcotullio, 2013; Elmqvist et al., 2013).

The Agenda 2030 of the United Nations explicitly takes into consideration the role of ecosystem services in an urban setting (UN, 2015). SDG 15 aims to conserve and restore the use of terrestrial ecosystems, reducing the loss of natural habitats and biodiversity which are part of our common heritage. Cities and human settlements have to become "more inclusive, safe, resilient and sustainable", stated in the title of SDG 11 (UN, 2015). In addition, they have to become "greener", which can be achieved through the widespread application of urban green technologies as support to ecosystem services.

The current environmental context involves the intersection of various sustainability challenges. This concept occupies an important place in contemporary politics, where its meaning has been well established to express the long-term conservation of entities of ecological value. It is undoubtedly very important to visualize various relationships whose role is to maintain the state of conservation over time. It is mainly about the following complementary relations. First, the relationship between society and environment: where the state of the environment mixes with the vital situation of the inhabitants of the area. Their well-being is directly related to their good health and quality of life. Second, the relationship between the urban environment and the economy: a report based on the establishment of economic well-being in a well-structured and ecologically sound urban area. Finally, another parameter plays a determining role in the sustainability of urban areas: the quality of ecosystem services. Being an extremely important provision for the ecological footprint of an urban area, it determines the rate of environmental vulnerability. The more these services are available and of good quality, the better for the sustainability of the city. This study touches on all three aspects of sustainability: social, economic and environmental, as well as their combinations.

Urban ecosystem services can have many economic (e.g job creation, energy efficiency, reduce community resistance to new developments), social (e.g reduction in waste volumes and public education), and environmental benefits (e.g. improved air quality and stormwater management and increase in urban biodiversity) (Jannson, 2014).

Ecosystem services can be successfully based on green infrastructures, technologies and practices that use natural systems, or engineered systems that mimic natural processes, to enhance overall environmental quality and provide utility services (Johnson, 2008). Conservation and restoration of natural capital, and therefore ecosystem services flowing from it, in urban areas can reduce their ecological footprints and enhance resilience, health and the quality of life of inhabitants (Sirakaya et al., 2018). They are increasingly addressed and studied as elements that help cities to adapt and mitigate the effects of climate change, achieve environmental benefits, enrich architecture, life quality and social and community behaviours (Bonoli et al., 2013). Many urban green infrastructures require availability of land space which is usually not feasible in densely built urban areas (Berndtsson, 2010; Gambi et al., 2011) and in densely urbanized areas there are few residual spaces that can be converted into green areas.

Urban areas have a higher average temperature than surrounding rural areas; this difference in temperatures is called the urban heat island effect (EPA, 2016; Leal Filho et al., 2017b). One of the primary services of green systems is the mitigation of the urban heat island effect. The UHIE mainly depends on the modification of the energy balance in urban areas due to several factors, such as: urban canyons presence (Landsberg, 1981), the thermal properties of building materials (Montavez et al., 2000), the large amount of hard high thermal surfaces, and the loss of green areas with impermeable ones reducing evapo-transpiration (Imhoff et al., 2010). It can be demonstrated by a robust connection between increasing green surfaces and the lowering of the corresponding temperature. An important study carried out by Susca et al. (2011), monitoring four areas of New York city, identified a difference of about 2 °C between green and grey areas, related to the substitution of vegetation with man-made building materials. This study demonstrated the importance of urban greening as a mitigation tool for the heat island effect. A similar trend is also seen in many urban centres round the world.

Another important effect of green areas is the reduction of the large percentage of impervious surfaces, causing a high volume of superficial run off and problems for storm water managements. Other benefits are related to the promotion of urban biodiversity (Brenneisen, 2006) and to improving air quality (Bass and Baskaran, 2003). Green technologies can also have an aesthetic value. Urban greening is promoted as an easy and effective strategy for regenerate degraded urban areas, beautifying the built environment and growing investment opportunity. Ecosystem services can serve a number of functions and uses, including community gardens, recreational space, meeting points, educational facilities and children's playgrounds. On one hand, an organized green space can be a source for community empowerment, increasing social cohesion. On the other hand, the combination of urban green areas with urban agriculture contributes to the creation of a local food system, improving the community's level of nutrition and reducing the urban footprint.

Because of the proven environmental, economic and social benefits, many states, cities and local institutions are giving direct and indirect incentives for the implementation of ecosystem services in urban areas. Investments in green infrastructure, or in urban ecological u7solutions for climate change adaptation are growing, mainly because such investments can produce other services enhancing human well-being concurrently (Elmqvist et al., 2013).

However, barriers encountered in promoting ecosystems are present in several countries. First of all, a lack of favourable government policies can be related to the lack of knowledge of environmental and social benefits derived by ecosystem services. In some old city context, i.e. medieval cities, the main barrier to green technologies could be related to the opposition of the superintendents to fine arts, because of a risk of change and disruption to the traditional aesthetic. Nevertheless, sometimes useful initiatives are present. The FAO's Incentives for Ecosystem Services (IES) approach (FAO, http://www.fao.org/in-action/incentives-forecosystem-services/policy/sdgs/en/) support farmers transition to sustainable agriculture. They also provide operative tools which supports effective actions achieving several interconnected SDG targets. Improving co-financing tools for multiple stakeholders (i.e. public and private sector, civil society, governments, etc.), can also help to foster partnerships and collaborations as well as a common commitment to SDGs achieving.

The correct approach has to incorporate a multi-stakeholder perspective, due to the wide spectrum of competences that must be involved. Unfortunately, lack of communication among different sectors of society and cities governance creates challenges in this topic. It is necessary to build connections and a sort of institutional and political network. Policy makers and local governance have to promote urban policies for a sustainable development on a territorial scale and a local level.

UES also have a positive effect on other similar entities. Indeed, urban ecosystem services can help safeguard other neighbouring ecosystem services. The experience of Berland et al. (2017) on the role of urban trees in controlling rainwater is especially helpful. These authors have shown that urban infrastructures are of major importance for the maintenance of other ecosystem services. This peripheral effect has a non-negligible role in the fight against climate change and may assist in fostering resilience against it (Leal Filho, 2020).

3. Methodology

Since this paper aims to review the current situation and provide an overview of how different cities handle their ecosystem services, the methodology is based on a qualitative comparative approach, with specific case studies outlining diverse urban ecosystems.

This systematic analysis was based on an integrated and multidisciplinary research framework. This framework included both primary and secondary sources of information, based on published and the collection of empirical data, such as physical ambient observations. The logical basis for the study and the interpretation of its findings follows the rationale of climate vulnerability and sustainability. Such a framework for climate change impact research combines the triple-bottom-line of sustainability (social, economic and environmental) with the cross-cutting issues of governance (Brugère and De Young, 2015) with a continuous feedback mechanism on adaptation and resilience-building systems. Therefore, cities with a significant level of vulnerability (or less adaptive capacity) would be prone to be impacted, and with lower degrees of sustainability in the face of climate change. Conversely, a resilient city, will seek to reinforce its adaptive capacity, including governance systems (Leal Filho et al., 2019).

The goals of the comparative enquiry are twofold. Firstly, it should help to develop an understanding of the phenomena involved, outlining how selected urban ecosystem services provide health, social and economic benefits, as well as contribute to climate resilience. Secondly, by deploying experiences from a set of 11 urban case studies from two geographical regions (Europe and Latin America), it may offer a good overview of the main issues which characterise and interpret the benefits brought about by those ecosystem services (Morlino, 2018) in two distinct regions. These two regions were chosen based on the need to identify possible contrasts in the ways industrialised and developing nations treat their ES in urban settings.

Additionally, the comparative approach with case studies has an *interventionist* goal. This objective attempts to identify suitable policies that, if well contextualised, could be applied to address the issues originally investigated (Morlino, 2018). The qualitative comparative approach has been widely used in climate change research, given its capacity to enable systematic comparisons of often diverse case studies (Rihoux, 2007). Application of this method can be found in the context of reducing emissions from

Table 1
Benefits of urban ecosystem services (UES).

UES benefits	Significance
Economic	direct or indirect monetary values provided by urban ecosystems[a]
Health	those obtained from ecosystem services, including reduction of air pollution, as well as improved water quality and mental health
Social	moral, spiritual, aesthetic and values associated with urban biodiversity and ecosystem services including emotional, affective and symbolic views attached to urban nature, as well as local ecological knowledge
Climate resilience	the capacity of an urban ecosystem to prevent, withstand, respond to and recover from disruption arising from a changing climate

[a] It is essential to acknowledge the methodological limitation of not having an assessment of the cost (value) of the driving forces, often indirect, which form these ecosystem services. Although progress has been made lately to quantify the value of such factors, it was not possible to include any valuation of these aspects in this study.

deforestation and forest degradation (REDD+) (Brockhaus et al., 2017), assessing water governance to deal with adaptation challenges (Pahl-Wostl and Knieper, 2014), and to investigate media attention to climate change (Schmidt et al., 2013).

In this study, the analysis of urban ecosystem services (UES) relies on data gathered from the sampled urban centres. It is based on a directed qualitative analysis performed by the authors aimed at addressing a fixed number of critical categorical benefits. This application builds on the two-step fuzzy-set qualitative comparison approach developed by Schneider and Wagemann (2006) but applies it by classifying certain benefits and trends (Likert scale with symbols), as shown in Table 2 below.

For instance, how urban ecosystem services are leading to health, social and economic benefits, as well as how they may help to improve climate resilience. This paper does not focus on the values of the driving (indirect) forces that form the ecosystem services, which are a substantial methodological problem today, but only on the direct, directly tangible or measurable ecosystem services. The following definitions were used (Table 1):

Besides, the benefits provided by the UES have been qualitatively assessed in each city using a standard qualitative scale (Table 2). Although qualitative, the approach is based on a series of quantitative indicators extracted for the analysed cities from the available European or national statistics. For example, the European Environmental Agency provides spatial data for analysing green infrastructure in Europe as a support for mapping ecosystem services (EEA, 2017) and also through the datasets for the Urban Atlas for Europe Project.[1] The thresholds for the qualitative classes proposed in the current paper are based on these assessments, considering their range in terms of share of green spaces in cities, but also the amount available per capita as well as the accessibility of green/blue spaces for citizens (Kabisch et al., 2016; Grunewald et al., 2017). The classes' delineation started from the World Health Organisation recommendation in terms of the ideal value of urban green space per capita of 50 m^2 per capita (Russo and Cirella, 2018). The spatial distribution was generally estimated using a recent CORINE land cover inventory of each city, looking at the uniform representation of the green/blue spaces per 1 sq. Km.

Although the general assignment of the city in a particular class still have a degree of subjectivity due to the difficulty to provide an average of each selected indicators for the entire city and to estimate the conditions of the infrastructure, at least the share of green/blues spaces and the allocation per capita were the leading indicators defining the classes thresholds.

For example, UES provides excellent benefits if the share of both green and blue areas is higher than 30% and per capita allocation is higher than 50 m^2. The other extreme is the class of inferior benefits, in the cities where the share of green/blue areas is below 5% and per capita allocation is lower than 10 m^2. However, the provided thresholds are indicative only, the authors assigned a city in a class or another considering the entire description of it, but also the geographical specificity of the city, having the possibility to upgrade or downgrade the class based on the whole spectrum of conditions. In terms of benefit trend shortly (next five years), the symbol has been attributed based on a revision of the municipality plans, if there are specific management measures regarding green/blue infrastructure both quantitative (to the extent the current area) or qualitative (to improve the quality of green/blue infrastructure).

The term "UES" used in this paper also refers to those services that are provided by urban ecosystems and their components (Gómez-Baggethun and Barton, 2013). In other words, those urban ES that is directly affected by planning decisions and actions at the urban scale. In this work, the case studies consider urban ES from Europe and South America, targeting different aspects: urban river network, food supply, urban water canals and ditches, urban parks and gardens, urban estuaries, urban agriculture, urban flood protection and urban green infrastructure. We applied the described method to a sample of 9 cities in Europe and Latin America: Hamburg (Germany), Bucharest (Romania), Mendoza (Argentina), Riga (Latvia), Montevideo (Uruguay), Tubarão (Brazil), Sofia (Bulgaria), Caracas - Chacao (Venezuela) and Valletta (Malta). Also, Bologna and Aveiro, as smaller cities, have been included in the analysis representing Italy and Portugal. The sample of cities is diverse, representing different geographical regions, settings and political contexts. It is also convenient, since the scientists who contributed to this study live in these cities, thus adding an element of local knowledge to the study.

This systematic analysis was based on an integrated and multidisciplinary research framework. This framework included both primary and secondary sources of information, based on both published and the collection of empirical data, such as physical ambient observations.

4. Results and discussion

The study presents and analyses the data from the 11 case studies from two geographical regions: Europe -with 7 case studies- and Latin America, with 4 case studies (Fig. 1). The authors provided a description of ecosystem services for each city, outlining the main benefits which have been assessed using a common qualitative scale.

A short description of each city in terms of specific elements related to the blue and green infrastructure is provided below. Table 3 highlights the heterogeneous distribution of green and blue spaces among the selected cities, outlining the share of these spaces as well as the allocation per inhabitants. In general, higher density cities lack a good share of green areas, outlining a low distribution per capita. However, when considering also the share of blue areas, the situation marks an improvement (e.g. the case of Valletta with a very low share of green areas, but a good share of blue areas).

[1] https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012.

Table 2
Classification and trends in the qualitative assessment of the UES benefits.

Benefit classification	Definition	Symbol
Excellent benefits	A very high share of green/blue infrastructure, in excellent conditions and having a good spatial distribution, green/blue area per inhabitants very high (>50 m^2/inhabitants), very high accessibility to people	+++
Good benefits	The high share of green/blue infrastructure, in right conditions and having an adequate spatial distribution, green/blue area per inhabitants high (30–50 m^2/inhabitants), high accessibility to people	++
Satisfactory benefits	Medium share of green/blue infrastructure, in acceptable conditions with an even spatial distribution within the city, % of green/blue area per inhabitants still high (15–30 m^2/inhabitants), relatively high accessibility to people	+
Poor benefits	The low share of green/blue infrastructure, in poor conditions, green area per inhabitants relatively small (5–15 m^2/inhabitants), uneven spatial distribution with many neighbourhoods that have low access to it, low accessibility to people	–
Inferior benefits	Meagre share of green/blue infrastructure, in deplorable conditions, % of green area per inhabitants very low (<5 m^2/inhabitants), uneven spatial distribution with many neighbourhoods that have deficient access to it, very low accessibility to people	–
Benefit trend	Definition	Symbol
Benefit increasing	it is estimated that benefits provided by green/blue infrastructure will increase or maintain at the same level in the next years due to several measures taken by the city municipality	↑
Benefit decreasing	it is estimated that the benefits will fall in the upcoming years due to insufficient management measures	↓

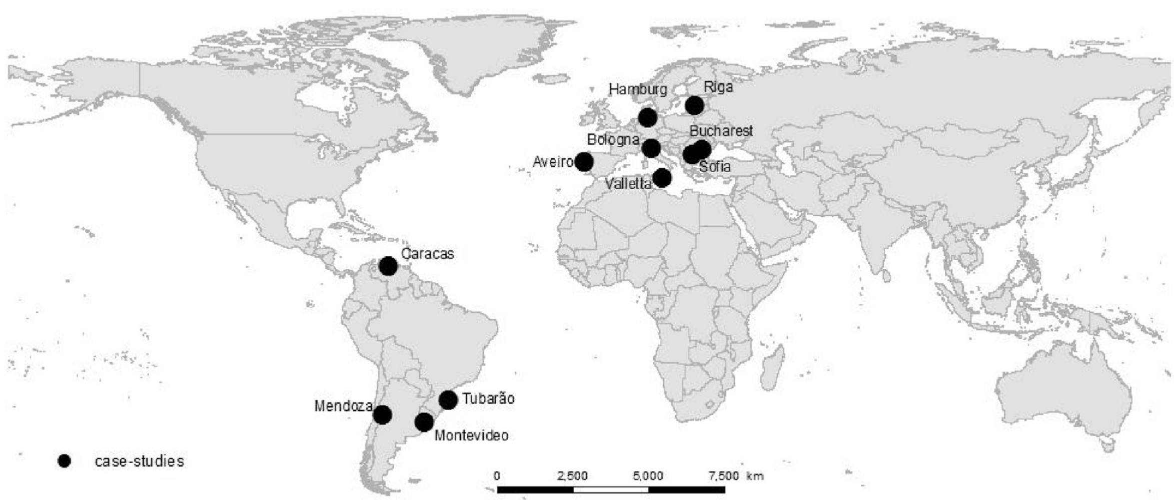

Fig. 1. The location of the eleven case-studies on urban ecosystem services.

Table 3
Green and blue infrastructure of the selected cities[3].

City	Population density (inhabitants/km^2)	% of green areas	Green area/inhabitants (m^2/per person)	% of blue areas	Blue area/inhabitants (m^2/per person)
Hamburg	2400	14.4	40	8	33
Bucharest	7690	8.6	9	3.8	4.2
Mendoza	2055	19.8	22	–	–
Riga	2060	29	132	16	71
Montevideo	2470	10	40	8	30
Tubarão	340	9	5	–	–
Sofia	2699	26.6	98.5	0.32	1.2
Valletta	7162	1.9	4.2	19.6	43.4
Chacao	5493	4	7	3	4
Aveiro	415	5	121	0.1	2.6
Bologna	3097	8	30	5.5	20.6

Northern European cities (e.g. Hamburg and Riga) show a good share of both green and urban areas, as compared to Eastern and Southern European cities (e.g. Bucharest, Valletta, Bologna) with a lower share of green areas.

The results gathered as part of the case studies are summarised in Tables 4 and 5, presenting health, economic and social benefits, as well as climate resilience in each of the studied cities. Out of eleven case studies, four are related with blue infrastructure of the city (urban rivers or canals) and seven are related to the green infrastructure (parks, forests, agricultural fields and green roofs). Green and blue infrastructures of the cities are the main pillars which offer benefits in terms of ecosystem services, and which help

[3] There are numerous sources for the data in the table: e.g. European or national statistics, as well as scientific publications. The authors preferred to use rounded values, not the exact data, to give an idea only of the extent of green/blue spaces in the selected cities, as a unitary basis for discussion.

Table 4
Case studies on ecosystem services and benefits provided in urban rivers/canals (Climate classification based on Köppen climate classification).

City, Country, Inhabitants, Area, Climate and Urban Ecosystem (UE)	Health benefits	Economic benefits	Social benefits	Climate resilience
Hamburg, Germany, 1,8 million; 755 km^2 Climate: "Cfb": Marine West Coast Climate UE: Urban River Network	Outdoor sport activities and landscape reduces stress	Use for tourism and transport of goods	Leisure opportunities (paddling, walks along the shores, etc)	Cooling of the urban area
Bucharest, Romania, 2.1 million, 228 km^2 Climate: "Dfa": Hot-summer humid continental climate UE: Colentina River's floodplain (green blue infrastructure, urban parks and lakes)	Sport activities, rowing, sailing, stress relief	Fishing, energy, tourism	Recreational areas (jogging, walking), education, cultural activities	Urban temperature regulation, water flow regulation, noise reduction
Aveiro, Portugal, 18,569, 44.8 km^2 Climate Csb: Mediterranean climate. UE: Urban Tidal Canal Network	Outdoor sport and leisure activities (Well-being)	Leisure, recreational and sport activities (Well-being) and Use for tourism.	Recreational areas (jogging, walking), education, cultural activities and leisure opportunities	Cooling of the urban area (Urban temperature regulation) and biodiversity support (avifauna)
Mendoza, Argentina, 1.5 million, 168 km^2 Climate: "Bwk": Cold desert climate UE: Urban water canals and ditches	The irrigation ditches irrigate the "urban forest" of Mendoza and this mitigates the "heat island" effect (Cad, n.d.). In this way, trees play an important role in providing a beneficial environment for habitat and development of the population, this acquires a special value in the natural environment as the semi-desert	In fact, irrigation ditches are part of a dense and complex urban and peri-urban irrigation system that irrigates city trees, but also irrigates agricultural production plots inland and on the outskirts of the city.	The irrigation ditches constitute one of the most important architectural-urbanistic patrimonies of Mendoza's identity. Being an urban oasis in the middle of an arid climate provides an immense social benefit in terms of urban landscape, in terms of cultural services	Water scarcity, floods, water pollution. Ditches and canals help drain urban areas during summer rainy periods.
Montevideo, Uruguay, 1.3 million, 527 km^2 Climate: "Cfa" Humid subtropical and "Cfb" Oceanic UE: Urban Estuary 22 km- long Waterfront promenade (La Rambla)	Outdoor sport and leisure activities	Use for nature-dependent tourism and leisure	Leisure opportunities (walks along the shores; sports; free outdoor gyms, etc.). Social integration and equity	Coastal protection and cooling of the urban area

to support a healthy urban environment (Gehrels et al., 2016).

Among the case-studies on blue infrastructure, three are located in Europe (Hamburg, Bucharest and Aveiro) and two in Latin America (Mendoza and Montevideo).

The Free and Hanseatic City (Freie und Hansestadt) of **Hamburg** is the second largest city in Germany, despite a territory of only 292 square miles (755 square km). The proportion of green areas in Hamburg is relatively high in comparison to most cities of similar size. Nearly 17% of the urban area is occupied by forests, recreation and green spaces. Water covers a further 8%, contributing significantly to the city's recreational opportunities. Waterfront terraces and walkways offer pleasant open-air environments for residents, while the River Elbe ferry lines serve the needs of both commuters and visitors (City of Hamburg, 2011). City of Hamburg, has one of the biggest blue infrastructures in Europe.

Bucharest, is crossed by Colentina and Dambovița rivers. The Colentina River is a plain river which meanders and has marshy areas. The Dambovița River is an extensively channelized river, with concrete embankments which crosses Bucharest from NE to SW through its centre. These two rivers and the human-made lakes of about 1200 ha (5.1%) are connected with green areas. There are about 35 green areas (parks) of various extensions that contribute to the groundwater recharge. Other urban ecosystems are represented by street trees, urban forests, and a large wetland area, Vacaresti Natural Park. The ecosystem is the main green area of the city, as well as the recreational one. Many parks, tourism and recreational activities being link to them. The main threats of the Colentina river ecosystems are related to wastewater discharge, which deteriorates the water quality (Carstea et al., 2013). According to the newest research (Gradinaru et al., 2018; Artmann et al., 2017), pastoral and gardening activities in urban areas of Bucharest are increasing.

In **Aveiro**, the city tidal channels comprise an important element of the urban ecosystem and is made up of branches from the Ria de Aveiro Lagoon system (Sousa et al., 2013). The City parks, channels and water mirrors (the largest one has been located in the city centre with 1.3 ha and landscaped area of 1.9 ha) contribute to the presence of more than 30 species of birds. The region in which the city of Aveiro occupies is also one of the four areas of greater biological diversity in the continental shelf of Portugal (Gomes

Table 5
Case studies on ecosystem services and benefits provided in urban green areas. (Climate classification based on Köppen climate classification)

City, Country, Inhabitants, Area, Climate and Ecosystem service	Health benefits	Economic benefits	Social benefits	Climate resilience
Sofia, Bulgaria, 1.3 million, 492 km^2 Climate: "Cfb": Temperate oceanic climate ES: urban green area	Reducing the risk of post – flood diseases, stress and injuries	Reduction of losses from floods and related disasters like erosion, landslides etc.	Increase of the level of environmental security and living comfort	Increase of the resilience to extreme precipitation and related hazards
Valletta, Malta, 6,000, 0.8 km^2, Climate: "Csa": Hot-summer Mediterranean climate, ES: green infrastructure	Physical and mental health benefits; improvement of air quality.	Tourist hot spots; income generation activities.	Facilitating social contact and interactions.	Atmospheric cooling of the urban area; minimisation of the urban heat island effect Improvement of air quality; sustained pollination and seed dispersal; sustained carbon sequestration and habitat provision.
Riga, Latvia, 0.7 million, 335 km^2. Climate: humid continental maritime ES: parks and gardens (blue-green structure), forests and forest parks.	Good air quality, mental and physical health Clean air, medical resources,	Markets, children's attractions, cafes, restaurants, shops. Wood production, berries and mushrooms as products, raw materials for cosmetics	Interaction between residents, place to ho ld social activities and events Hiking trips, education about nature diversity	Reduces pollution from the city streets, habitat for species and exotic plants, improvement of hydrological cycle. Regulate the air quality
Bologna, Italy, 389,000, 140 km^2, Climate: temperate continental. ES: green roofs	Reduction in respiratory diseases provoked by air pollution Flood risk reduction Well-being improvement	Energy saving Water recovery and reuse possibilities Pollution reduction (community health costs reduction)	Well-being improvement Socialization improvement (community horticulture and gardens) Pollution reduction	Rainfall water collection and run off reduction Urban Heat Island effect reduction
Chacao, Caracas, Venezuela, 70,713, 13 km^2 Climate: "Aw": Tropical dry ES: urban parks and climate comfort.	Reduces incidence of respiratory diseases from air pollution, outdoor sport activities, extensive public green areas	Attractive for high income commercial and real estate activities; attractive for leisure and recreational activities, both for local neighbours and neighbouring municipalities.	High quality housing & built environment Plenty of mixed developments Large green canopy Structured cultural development The lowest criminal record in the city High class neighbourhoods and high community values	Reduces heat waves stress The extensive coverage of forests around and within the city constitutes an important substrate for carbon sequestration
Tubarão, Brazil, 104,937, 301 km^2; Climate: "Cfa": Humid subtropical climate ES: Agriculture	Food and nutrition security	Research and Development, food production	Community development	The impacts that agriculture is providing for the economy and the negative impacts on biodiversity

et al., 2018). The surrounding wetlands, which extend to more than 40 km to the North, are rich in flora and fauna. There is growing tourist activity, with the region received more than 3.8 million tourists in 2017 of which 42.9% were to non-national tourists (INE, 2012). This is due in part to the areas natural, scenic, gastronomic and cultural beauty, associated with a set of interconnected ecosystems that extend to the South and North.

In Latin America, **Mendoza** city is located by the Andes Mountain Range. Despite having an arid climate (annual rainfall 200 mm) it is an urban oasis which represents a unique case in the urbanism of arid zones. The merit of this type of city is to adapt a desert area environmentally, transforming it into a place with conditions exceptionally suitable for human life (Bormida and Dabul, 1997). The urban oasis of Mendoza is an ecosystem which consists of a natural infrastructure of irrigation grids and a network of street trees that accompanies the urban buildings. The network of irrigation ditches created in the 16th century is still preserved, making it a kind of "laboratory city" (Brandi, 2016). Mendoza's system of irrigation ditches and urban woods is an ecosystem that contributes directly, and indirectly, to the provision of ecosystem services in the city (gas regulation, microclimate regulation, noise and disturbance reduction, rainwater drainage, waste absorption, recreational and cultural services), providing health, economic and social benefits. Currently, the services provided by this urban oasis ecosystem (composed of irrigation ditches and street trees) are threatened by human actions and climate change.

Montevideo, the capital city of Uruguay, is over the broad Rio de la Plata River Estuary with a total length of over 40 km. The coastal promenade, "La Rambla", which is 22 km long and was built from 1938 to 1942 is the most emblematic landscape, cultural and touristic feature of the city. Sandy beaches, rocky shores, and a yacht port, characterise la Rambla, as well as a wall which protects the built environment from storm surges that ravaged the coast between 1923 and 1935 (Gutiérrez et al., 2015, 2016). This large and popular blue area and associated infrastructure is the heart and lung of the city, because a large percentage of the city's population, as well as tourists, go to the beach or to the promenade, to walk, run and do exercise in free public open gyms. Despite the high level of urbanization, this blue area still has some preserved natural landscapes and ecosystems, mainly sandy dunes, and serves as a buffer and a climate regulator of the city.

Summary of the health, economic and social benefits, as well as climate resilience, of the above described blue infrastructures is presented in Table 4.

In general, these urban areas have a large proportion of blue infrastructure (urban rivers or canals), with the most common benefits being health and well-being (e.g. different sport activities), economic benefits - tourism, social benefits – leisure activities, and climate resilience – cooling of the urban areas (Völker and Kistemann, 2011; Grellier et al., 2017). Cities where blue infrastructure is well represented also have very good green infrastructure, such as rivers or canals being accompanied by vegetation; therefore these cities are expected to provide a healthier environment which contributes to sustainability.

Green areas in cities provide multiple benefits to people in terms of health and well-being, thus their assessment is targeted by many studies (Lee et al., 2015; Wheeler et al., 2015; WHO, 2016; Lennon et al., 2017; Barton and Roigerson, 2017). Although it is not easy to assess their contribution in monetary terms (Gehrels et al., 2016), it is acknowledged that many cities are facing the problem of insufficient green infrastructure to support healthy living and an adequate environmental quality.

In the other six cities included in this study four are European (Sofia, Valletta, Riga and Bologna) and two are South American (Chacao, and Tubarao). The main focus of these cities is on their green infrastructure and benefits human can obtain from it.

In **Sofia**, urban green areas provide significant protection against floods, which is considered to be the most important ES. In Sofia, the temperature and precipitation extremes have negative impact on the people's health and on the built infrastructure. They are represented mainly by cold and hot spells, hail storms and floods. Precipitations of 64 mm/24 h (August 06, 2005) and 63 mm/24 h (May 27, 2014) cause floods in many parts of the city (NSI, 2016). The losses from the severe hailstorm on July 08, 2014 were more than 50 billion euro (NIMH, 2014). Both, climate change, fast urbanization and the economic development of the Sofia district influence the ecosystems conditions, and their capacity to provide particular services. The capacity of urban green areas in Sofia to reduce flood risk improves the resilience to extreme precipitation, providing water retention services and increasing the level of environmental security and living comfort (Nikolova et al., 2018).

In **Valletta**, urban green infrastructure improves air quality, which is an important human health benefit. Large trees tend to filter pollution more so than the common small trees and bushes that are found in these types of gardens. Most of these trees are coniferous, and therefore tend to have a larger filtering capacity than deciduous ones. According to Tolly (1988), and Bramryd and Frabsman (1993), 1 ha of mixed tree area can remove 15 tonnes of particulates per year from the air. Following recent studies on the effects of air pollution on life expectancy and premature deaths, green infrastructures assume an even greater role. These green spaces generate employment and boost tourism, which is an important economic benefit. The upper and lower Barakka gardens attract many Maltese and tourists all year round. Recreational and cultural values are perhaps the highest values that ecosystem services can offer to the city of Valletta. This is due to the high aesthetic value intertwined with the cultural and historical elements, lending structure to the city's fortified landscape. The presence of fauna such as birds and insects should also be accounted for in this recreational value. Considering climate resilience in Valletta, according to Hough (1989), a single large tree can transpire 450 L of water per day, consuming in the process some 1000 MJ of heat energy to drive the evaporative process.

In **Riga,** the idea of nature (ecosystem services) as an element of urban infrastructure is part of the tradition of the city. Green infrastructure in the city includes urban forests, parks, single trees and the characteristic presence of green belts (for example parks surrounding Old Town), as well as city forests on the outskirts. A survey of inhabitants identified parks and urban forests (Straupe and Liepa, 2018) as significant for urban tourism. While a recognition of the importance of urban forest ecosystems as a contributor to the resilience of the city is growing, recreational pressure and demands for aesthetic and natural landscapes are significant. The effectiveness of the ecosystem services provided by city parks and forests have been largely shaped by recreation loads (Jankovska et al., 2014) as well as weak democratic traditions and a civil society trying to protect infrastructure important for the delivery of ecosystem services (Angelstam et al., 2018).

The City of **Bologna** is a founding member of ICLEI, the international network of governments for sustainability, partner of Eurocities and Local Agenda 21 in Italy. Upon acceding to the Aalborg Commitments (2006) and the Covenant of Mayors (2008), the city of Bologna strengthened its presence among the European cities active in the field of sustainable development, aiming for the development of solutions for sustainable resource management in a time of profound economic and social changes, mainly in relation to climate change. A general greening of the city, such as the construction of ecological corridors, permeable pavements and green roofs implementation, is taking place. Green roofs in particular, could provide several benefits, for instance:

a) health (in terms of air pollution reduction, flood risk reduction and a more generalized improvement in well-being),
b) economic benefits (energy saving, water recovery and reuse possibilities, pollution reduction and related community health costs reduction) and
c) social benefits, in respect to the increase in well-being

Green Roofs can also contribute to urban resilience against climate change due to surface water run off reduction, rainfall water collection and storage, urban heat island effect reduction and energy saving.

In **Chacao** city, the main ecosystem services provided are: Reduction of the effects of heat waves stress and the incidence of respiratory diseases from air pollution, climate comfort throughout the year and an important substrate for carbon sequestration (Table 4). The "Plan Chacao" has been developed as the first Plan of Local Urban Development of Venezuela that includes the risk variable. Through the Institute of Civil Protection and Environment (IPCA), the "Environmental and Risk Management Plan of the Chacao Municipality 2011–2016″ was developed. The IPCA manages participation with key actors through programs such as Citizen self-protection (community), Corporate Self-protection (Companies), School Self-protection (Schools), Eco-schools (Certification in environmental management ISO 14.001 for the Municipal Schools), with a high-performance team highly trained in the work of reduction of disaster risks. The "Security Business Network" and Emergencies of the Chacao Municipality", which includes more than 50 large private corporations located in the municipality, has permanent training of its staff in work prevention and risk mitigation and coordinated action in case of adverse events. Ongoing new projects related to the resilience of the communities settled in spaces with greater natural risk, such as the emblematic case of the El Pedregal popular sector, through the management of the middle basin of the Chacaíto creek (HFA, 2013).

Tubarão municipality has a large cultivated area of 58,050.00 Ha, equivalent to 77.69% of the total area destined for agriculture in the municipality (EPAGRI, 2019). When it comes to the Brazilian reality, family farming is a great incentive for the population's food security (Berchin et al., 2019), corresponding to 84.4% of the rural units in Brazil. Agricultural innovations can contribute to more food production on a smaller amount of land, better utilization of available resources, and lower expenditure on rural and peri-urban producers (Gaffney et al., 2019).

In the above mentioned six cities included in this study (Sofia, Valletta, Chacao, Riga, Bologna and Tubarao) the benefits provided by urban green areas (parks, forests, agricultural fields and green roofs) have been analysed and the results are summarised in Table 5.

The qualitative assessment of the benefits provided by ecosystem services for each of the case-studies (Table 6) reveals a better score obtained by the cities relying on blue infrastructure, which is associated with the green one, compared to the ones where mostly green infrastructure is important.

It can be seen that health and economic benefits have been rated the highest, showing an increasing trend in the future for most of the cities (9 from 11). This is compared with social benefits, that have also been rated as high (satisfactory and good) for most cities, but with a decreasing trend for the future for 3 cities. Climate resilience has been scored as positive and on an increasing trend only for 6 cities (Bologna, Hamburg, Aveiro and Sofia having the highest rating). For 3 cities (Bucharest, Mendoza, Montevideo), although scored as positive, there is a decreasing trend for the benefits in the future. This is mainly due to the inappropriate management of the blue/green infrastructure and lack of climate mitigation or adaptation measures. Two cities (Valetta and Chacao-Caracas) have been scored as having poor benefits, meaning that the green infrastructure is in poor condition, with many neighbourhoods having low access to it.

For the cities rated with the highest scores (very good benefits and an increasing trend) such as Bologna, Hamburg and Aveiro, the natural settings of each city are supported by several measures taken by city municipalities. For example, in Bologna, the Green Roof implementation measure greatly increased the amount of green areas, and contributed to decreasing pollution, with climate resilience benefits. For Aveiro, the natural setting, with an extensive wetland area (Ria de Aveiro) showed high biodiversity. The proximity of the sea also contributes to good scores for all analysed categories of benefits.

The city of Tubarão, which strongly relies on agricultural ecosystems (especially irrigated rice production), was ranked with a high score, mainly for the economic and social benefits. This is mainly due to the agricultural programmes implemented by the municipality to encourage participation in the community and to promote innovative agricultural technologies.

In contrast, Valletta city (Malta) has been rated as providing the poorest benefits, due to the unfavourable natural settings and human-induced factors: green space is constantly required for built infrastructures.

A negative score for the benefits related to climate resilience has also been obtained by the city of Caracas. This is due to the likely threats that climate change pose to the city and the weak reaction of authorities to the maintenance of an early warning system which would improve response times to the expected impacts of climate-related events (e.g. increased El Niño/La Niña events, and heatwaves). This is also the case in Mendoza. Particular features of the city, in terms of urban ecosystems (irrigation ditches being one of the most important architectural-urbanistic patrimonies of Mendoza's identity (Bormida and Dabul, 1997), have a role in ensuring the city drains during summer rainy periods. However, green infrastructure could be threatened due to long term water shortages.

For Bucharest, climate resilience is expected to slightly decrease due to the urban fabric extension, as well as the likely changes in the climate (e.g. rainfall frequency and intensity, mean temperature increases). A similar trend follows in Montevideo, with climate-induced threats related to sea level rise, storm surges, increased El Niño/La Niña events which could erode the beach, as well as the promenade's wall. The municipality has taken measures to increase its resilience and reduce these impacts, but they are not enough under an SLR scenario (Gutiérrez et al., 2015, 2016).

Sofia and Riga show a decreasing trend in terms of social benefits, due to the low level of involvement of authorities.

From the analysis of the 11 cities situated in different geographical settings, it can be seen that the most pressing issue for them is the better deployment of ecosystem services in their attempts to foster climate resilience. Specific measures need to be planned and implemented by the administrations of these cities, so as to upkeep the ecosystems services they host. There are three main pathways which cities may follow, in order to maximise the role of ecosystem services in the sustainability of the urban environment (Fig. 2).

In Pathway I, urban planners should focus on restoration efforts. In Pathway II, city authorities should explore new opportunities for the better deployment of ES, creating additional opportunities. In Pathway III, the focus is on a better integration of ecosystem

Table 6
Qualitative assessment of the benefits provided by the UES.

City (Country)	Health benefits	Economic benefits	Social benefits	Climate resilience
Blue infrastructure				
Hamburg (Germany)	++↑	++↑	++↑	++↑
Bucharest (Romania)	+↑	+↑	+↑	+ ↓
Aveiro (Portugal)	++↑	++↑	++↑	++↑
Mendoza (Argentina)	+↑	+↓	++↑	+ ↓
Montevideo (Uruguay)	+↑	+↑	+↑	+ ↓
Green infrastructure				
Sofia (Bulgaria)	+↑	+↑	+↓	++↑
Valetta (Malta)	−↓	-↓	-↓	-↓
Chacao, Caracas (Venezuela)	+↑	+↑	+↑	-↓
Riga (Latvia)	+↓	+↑	+↓	+↑
Bologna (Italy)	++↑	++↑	++↑	+++↑
Tubarão (Brazil)	+↑	++↑	++↑	+ ↑

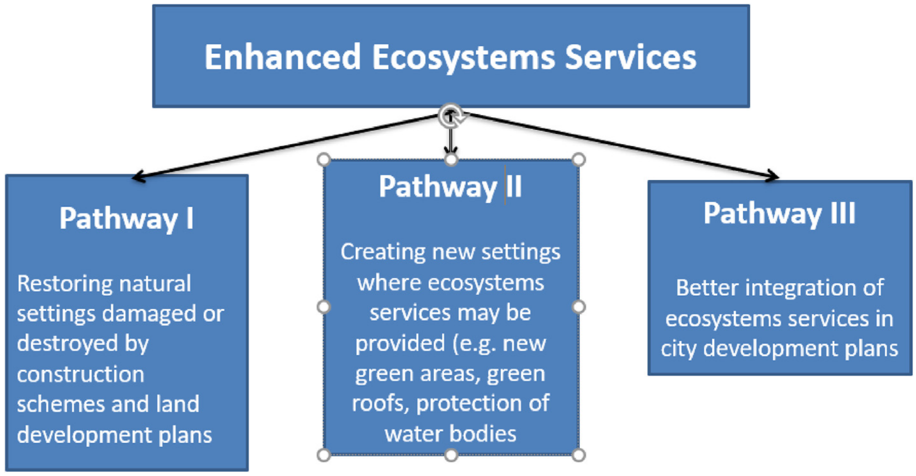

Fig. 2. Some pathways to maximise the role of ecosystem services.

services in future city development plans. The variety of pathways outlined in Figure illustrate the variety of possible methods which can be deployed by various stakeholders (e.g. city planners, government offices, researchers, etc) in order to implement the principles of UES in practice.

As this multi-country analysis has shown, these pathways and their implications need to be carefully considered. This is in order to realise the potential of ecosystem services in promoting a healthier and by default, a more pleasant living environment.

5. Conclusions and policy recommendations

According to the United Nations, around 68% of the world's population will live in cities by the year 2050. It is therefore very important to improve our knowledge of the environmental problems seen in urban areas, especially those connected with climate change specific pressures and threats. Intervention on the state of ecosystems remains the key to any future conservation initiative. By applying the right conservation strategies, urban areas can continue to maintain their dynamism. Their evolution is directly related to the presence of ecosystem services in the living space, and the maintenance of these flows is a priority.

In general, it is noticeable in all case studies that, in terms of health benefits, outdoor sport activities and physical and mental health were the most commonly mentioned services provided by ecosystems.

In respect to economic benefits, tourism and leisure activities were the most frequently mentioned ones. The sample also suggests that the most relevant social benefits are linked to community interactions, and from recreational areas, which together lead to improved quality of life in general. Finally, in respect to climate resilience, there are multiple benefits provided by the ecosystems in terms of temperature regulation, decreased exposure to the impacts of extreme events (by means of natural barriers to water or to droughts), biodiversity conservation and improved air quality. There are some limitations to this work. For instance, the sample of cities is not large enough to allow definitive conclusions to be drawn However, this paper builds a rough profile of current trends seen today, in respect to the role played by ecosystem services in building a sustainable urban environment. A number of policy recommendations may derive from the study. Some of them are as follows:

a) there is a need to document successful case studies on ecosystem services and the benefits they provide. In this paper the authors have listed the ones in urban rivers/canals (Table 4) but more efforts are needed. The same line of thinking applies to case studies on ecosystem services and benefits provided in urban green areas (Table 5);
b) more qualitative assessments of the benefits provided by the UES should be encouraged by policy-makers, since they may provide basis upon which investments may be pursued. In times of constraints in city budgets, it is important to illustrate the advantages of UES so as to facilitate political decisions about them;
c) if not yet performed, a comprehensive valuation of the ES in a given city should be undertaken, so as to prioritise areas where actions are needed in the short, medium and long-term. By doing so, city administrations should be able to pay a greater attention to the potential of urban ecosystem services for improving the resilience and quality of life in their cities. This can be implemented, for instance, by ensuring that building projects are not pursued to the disadvantage of green areas, or by implementing building codes which seek to reduce the risks of urban heat islands (for instance, by green roofs or facades);
d) more use should be made of smart technologies in city development plans, to better monitor, model and assess the environmental consequences and risks related to the depletion of ES;
e) as the 3 pathways on Fig. 2 show, municipal strategies to foster ES and achieve a successful sustainable urban development, should deploy approaches to restore ES (Pathway I), to explore new opportunities for the better deployment of ES (Pathway II) and focus is a better integration of ecosystem services in future city development plans (Pathway III). They all should include an integrated design and management of green infrastructure. Going further than upkeeping green areas, it should include water and waste management, run-off purification and remediation of urban soils.

Also, whenever not yet available, working groups on ES could be established, and engage policy-makers and municipal services on the one hand, but also landscape architects, civil engineers, and other stakeholders in urban management, on the other. The participation of the community is also vital in this process.

Many other policy recommendations could be added to this list, but the above measures may be helpful in providing a sound basis upon which ES could be better embedded on a city's structure.

Overall, this paper has reviewed the role of ecosystem services as tools for sustainability, based on an urban setting. It has also described a series of multi-country case studies, where an assessment of their functions using a set of benefits valuation approaches is provided, along with an appraisal of their role in up-keeping the overall quality of the urban environment in the studied areas. The policy recommendations here provided, are aimed at enhancing the role of ecosystem services, and fostering sustainability in the sampled sites -and beyond. When implemented, they may help cities to properly safeguard the ES they benefit from. Considering also the higher exposure of citizens living in cities to air pollution, creating or at least maintaining green and blue infrastructure should be a priority for municipalities round the world.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Walter Leal Filho: Writing - original draft, Writing - review & editing, Conceptualization. **Jelena Barbir:** Writing - original draft, Writing - review & editing, Formal analysis. **Mihaela Sima:** Writing - original draft, Writing - review & editing, Supervision. **Alexandra Kalbus:** Writing - original draft. **Gustavo J. Nagy:** Writing - original draft, Writing - review & editing, Formal analysis. **Angelo Paletta:** Formal analysis, Writing - original draft. **Alicia Villamizar:** Formal analysis, Writing - original draft. **Reinaldo Martinez:** Formal analysis, Writing - original draft. **Ulisses M. Azeiteiro:** Formal analysis, Writing - original draft. **Mário J. Pereira:** Formal analysis, Writing - original draft. **Paula C. Mussetta:** Formal analysis, Writing - original draft. **Jorge D. Ivars:** Formal analysis, Writing - original draft. **José Baltazar Salgueirinho Osório de Andrade Guerra:** Formal analysis, Writing - original draft. **Samara de Silva Neiva:** Methodology, Formal analysis, Writing - original draft. **Stefano Moncada:** Formal analysis, Writing - original draft, Writing - review & editing. **Charles Galdies:** Formal analysis, Writing - original draft. **Maris Klavins:** Formal analysis, Writing - original draft. **Mariyana Nikolova:** Formal analysis, Writing - original draft. **Radu C. Gogu:** Formal analysis, Writing - original draft. **Abdul-Lateef Balogun:** Formal analysis, Writing - original draft. **Aicha Bouredji:** Writing - original draft. **Alessandra Bonoli:** Formal analysis, Writing - original draft.

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