URBAN GreenUP

D7.3: Guidelines for the application of ESA methodology in different contests

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0 Executive summary

The deliverable 7.3 “Guidelines for the application of the ESA methodology” aims at analysing and provide a comprehensive framework of the methodologies and tools available for the evaluation of the ecosystem services provided by NBS at the urban level.

URBAN GreenUP project will valuate the ex-ante and ex-post impacts generated through the implementation of NBS in front-runner cities through the adoption of the methodology based on the Ecosystem Services Assessment (ESA). The individuation of the ecosystem services provided will ensure the inclusion of all impacts and benefits of NBS into the economic analysis.

At the moment, some several methodologies and tools can be adopted to valuate the economic impacts of ecosystem services, but just a few of them can be used at the urban level. In fact, in most of the cases analysed (worldwide), the valuation was referred at regional, national, or landscape scale.

Four main blocks compose the deliverable:

1. Definition of the connection between the NBS, the ecosystem services, and natural capital;
2. Description of the methodologies used for the economic valuation of ecosystem services at urban level;
3. Description of the tools for the ecosystem service economic valuation of ecosystem services at urban level;
4. Definition of the guidelines for the ecosystem services valuation at the urban scale.

Two documents are attached at the deliverable. The first one summarises the methodologies for the economic valuation of the ecosystem services generated by NBS with related examples and cases study. The second document summarises the tools used for economic valuation. This derivable will be used as the base to perform the ex-ante economic valuation of the NBS implemented in front-runner cities: Valladolid, Liverpool, and Izmir.

1 Introduction

Ecosystem services are “the direct and indirect contributions of ecosystems to human wellbeing,” and they can help to cope with the significant challenges that cities are facing nowadays. Healthy ecosystems can regulate city temperature, reducing the heat island effect, reduce water run-off, and improve human health and the overall resilience of urban areas. At the same time, urbanisation has increased the pressure on natural resources, generating several impacts on the ecosystems and the services provided by them at local, regional, national, and global scales. This phenomenon has been exacerbated by the impacts of climate change, increasing vulnerability to natural disaster risks.

Cities are the leading growth centres of population, consumption, resource use, and waste (Folke et al., 1997). Many of cities’ basic needs depend on nature’s ecosystem services. Air quality is a primary concern for cities because it seriously affects human health – with potentially deadly and disabling effects. Air pollution represents a significant economic threat. In the face of water shortages, cities are increasingly taking responsibility for water management (Carter, 2011). A wide range of ecosystem services come from the natural spaces in and around cities. They clean the air and water, temper floods, provide water and food, reduce noise, increase physical and psychological wellbeing, regulate the local climate, sequester CO2, and provide renewable energy (WWF, 2013).

At the international and national level, several policies for the protection of ecosystems has been defined. Indeed, regional and local authorities can improve integrated spatial planning and coordinated management between sectors to reduce the pressures on the natural system (Croci and Lucchitta, 2018).

A better understanding of the ecosystem services economic value provided by NBS will facilitate their implementation at the urban level and the engagement of stakeholders. The knowledge of the economic value and the cost-efficiency of NBS can facilitate the adoption of these solutions at the urban scale. Through the application of an ecosystem-based assessment – the Ecosystem Services Assessment (ESA) - it will be possible to capture all the impacts and benefits generated by NBS.

Even if different studies have been developed to show the value of ecosystem services and NBS, the application of these methodologies still represents an issue. The aim of this report is to i) carry out and in in-depth analysis on the economic valuation methodologies for the ecosystem services valuation at local level, ii) identify the case studies for the ecosystem services valuation at urban level through a literature review, iii) define guidelines for the application of the ESA for the valuation of NBS impacts in cities.

1.1 Purpose and targets groups

WP7 of Urban GreenUP project is focused on exploitation and market deployment as well as on the ex-ante economic valuation of NBS in Front-runner cities: Valladolid, Liverpool and Izmir. Specifically, Task 7.1 aims to define the methodology for the economic valuation performance of NBS based on the ecosystem services approach and to adopt this approach to perform the ex-ante economic valuation of NBS. This deliverable (7.3) describes:

- the methodology used for ecosystem services valuation at urban level;
- the tools used for ecosystem services valuation at urban level;
- the guidelines for the economic valuation of ecosystem services at urban level.

The main target groups of this deliverable are the partners of the Urban GreenUP project, front-runner and follower cities. The deliverable can also be of interest for other cities, their technical and business partners, who wish to acquire information on economic valuation of NBS impact generated in cities and on Urban GreenUP specific approach on this.

1.2 Connection with other project activities

The following table summarises the main relationship of this deliverable to other activities (or deliverables) developed within Urban GreenUP Project and that should be considered along with this document for further understanding of its contents.

Partner	WP	Relation
ACC	WP1	Definition of the Renaturing Urban Plan
VAL	WP2	Implementation of NBS in city and definition of financing schemes for the co-financing of the nature based solutions. Monitoring and analysis of the performances.
LIV	WP3	Implementation of NBS in city and definition of financing schemes for the co-financing of the nature based solutions. Monitoring and analysis of the performances.
IZM	WP4	Implementation of NBS in city and definition of financing schemes for the co-financing of the nature based solutions. Monitoring and analysis of the performances.
RMT	WP6	Characterisation of front runner cities Cluster of cities to foster transferability Link with other SSC-02 projects

Table 1: Relation to other project activities

2 NBS, ecosystem services and natural capital

Natural capital and ecosystem services have gained more and more attention at the international and local level to cope with the significant challenges that national and subnational governments are facing nowadays since nature can be used to provide effective solutions deploying the properties of natural ecosystems (MA, 2005; TEEB, 2010; EC, 2013). Natural capital is defined as the world's stocks of natural assets, which include geology, soil, air, water, and all living things. It is from this natural capital that humans derive a wide range of services, often called ecosystem services, which make human life possible (Natural Capital Coalition, 2012). Ecosystem services are "the direct and indirect contributions of ecosystems to human wellbeing" (see figure 1, TEEB 2010). Several classifications of ecosystem services exist, including those presented by the Millennium Ecosystem Assessment (MA 2005), TEEB (TEEB 2010) and the Common International Classification of Ecosystem Services (CICES 2013). The MA individuates four categories of ecosystem services:

1. **regulating** (benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases);
2. **provisioning** (products purchased from ecosystems; may include food, fresh water, timber, fibers, medicinal plants);
3. **cultural** (non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values);
4. **supporting** (services that are necessary for the maintenance of all other ecosystem services).

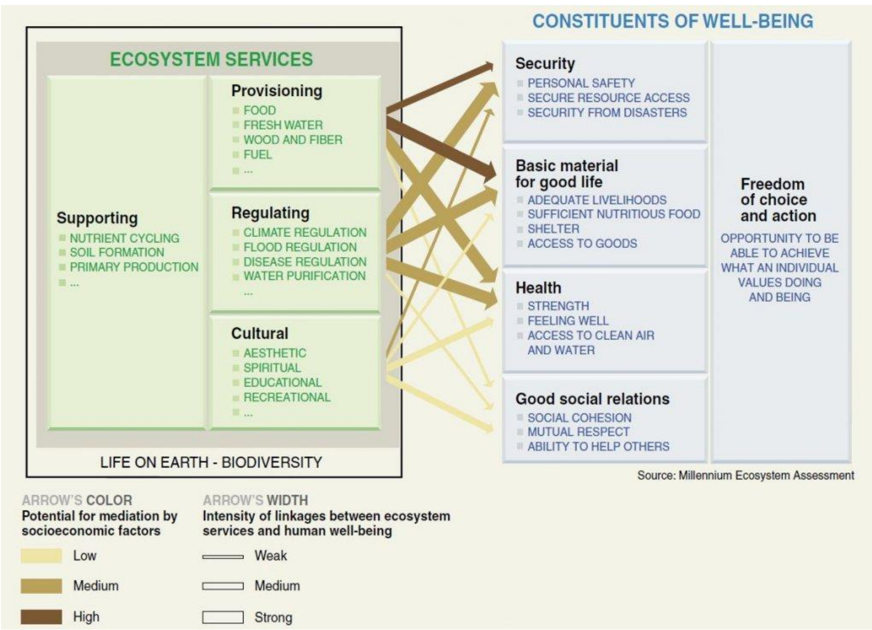


Figure 1: Ecosystem services and human well-being (MA, 2005)

The figure below summarises in detail the ecosystem services identified by the CICES and the TEEB starting from the standard definition of the 4 ecosystem services categories: regulating, provisioning, supporting and cultural.

	CICES	TEEB	DEFINITION
REGULATING	Regulation of bio-physical environment	Air quality regulation	Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere
		Waste-water treatment	Ecosystems such as wetlands filter effluents and break down most waste through the biological activity of microorganisms in the soil
	Flow regulation	Moderation of extreme events	Ecosystems create buffers against natural disasters, thereby preventing or reducing damage from extreme weather events
		Regulation of water flows	Vegetated areas contribute to prevent and mitigate negative effects in several ways by intercpeting water or through percolation
		Erosion prevention	Vegetation cover provides a vital regulating service by preventing soil erosion
	Regulation of physico-chemical environment	Moderation of extreme events	Trees and green space lower the temperature in cities whilst forests influence rainfall and water availability both locally and regionally
		Regulation of water flows	Ecosystems regulate the climate by storing GHG. Trees and plants remove carbon dioxide from the atmosphere and lock it away in their tissues
		Erosion prevention	Soil fertility is essential for plant growth and agriculture and well-functioning ecosystem supply soil with nutrients
	Regulation of biotic environment	Pollination	Insects - but also some birds and bats - and wind pollinate plants which is essential for the development of fruits, vegetables and seeds
		Biological control	Ecosystems regulate pests and vector borne diseases that attack plants, animals and people through the activities of predators and parasites
PROVISIONING	Nutrition	Food	Ecosystems provide the conditions for growing food for human consumption
	Regulation of biotic environment	Fresh water	Ecosystems play a vital role in providing cities with drinking water, as they ensure the flow, storage and purification of water
	Regulation of biotic environment	Raw materials	Ecosystems provide a great diversity of materials for construction and fuel that are directly derived from plant sepcies
		Medicinal resources	Biodiverse ecosystems provide many plants used as traditional medicines as well providing raw materials for the pharameceutical industry
CULTURAL	Intellectual and experiential	Recreation,mental/physical health	Walking and playing sports in green space is a good form of physical exercise and helps people relax
		Aesthetic appreciation and inspiration	Environment is related throughout human history. Biodiversity, and landscapes have been the source for much of our art, culture and science
		Spritual experience and sense of place	Customs associated to nature are important for creating a sense of belonging
		Tourism	Ecosystems play an important role for many kinds of toruism which in turn provides considerable economic benefits
SUPPORTING	Not present	Habitats for species	Each ecosystem provides different habitats that can be essential for a species' lifecycle
		Maintenance of genetic diversity	Genetic diversity distinguishes different breeds or races from each other, providing the basis for locally well-adapted cultivars and a gene pool for developing commercial crops and livestock

Figure 2: Ecosystem services classification. UB elaboration adapted to CICES and TEEB

Starting from Costanza's work on the value of ecosystems worldwide (Costanza, 1997), a growing number of studies have proposed methods and applications for the assessment of the impacts and benefits generated by healthy ecosystems. In the last decade, a growing consensus has emerged on the importance of ecosystem services and their integration in the management of natural resources and territorial planning (Daily et al., 2009; de Groot et al., 2010; Tratalos et al., 2007). Countries implementing policies and actions to enhance ecosystem services are generally more resilient and less vulnerable to extreme natural events. The resilience of a system is defined as the ability to suffer a shock (Walker et al., 2004), maintaining its functions and characteristics and recovering the initial conditions. External shocks such as floods, landslides, droughts, and heatwaves can cause negative consequences at social, economic, and environmental systems. The natural capital of an area performs an "insurance" function towards the impacts of changes underway, including climate change (green et al., 2016).

NBS are recognised for being multi-function, multi-purpose, and multi-beneficial (EEA, 2015). NBS are actions "inspired, supported by or copied from nature" (EC, 2015) that use complex system processes of nature to reduce disaster risk, to improve human well-being and to promote a socially inclusive green growth. The European Commission has introduced this topic through COM(2013) 249 final "Green Infrastructure (GI) — Enhancing Europe's Natural Capital." Furthermore, NBS can deliver services, such as the ability to regulate water or store carbon, comparable to traditional, grey infrastructures in a more cost-efficient way. In cities, for example, urban parks and green areas, in general, can offer ecosystem services such as storm control, carbon dioxide conversion, wildlife diversity, outdoor recreation opportunities, noise dampening and offsetting city pollution.

NBS can reinforce ecosystem services at the urban level, creating or enhancing the connections between urban and natural areas. There are several examples of NBS that can be implemented in cities. Some of them are green roofs and walls, urban parks and gardens, green corridors, river stream restoration, streets greening, urban farming, sustainable urban drainage systems, temporary flooding areas, and urban forests. Examples of essential urban ecosystem services provided by NBS include (see figure 2):

1. reduction of local air pollution (Gomez-Baggethun et al., 2013);
2. microclimatic regulation: heat island phenomenon reduction and temperature increase due to climate change (Schwarz et al., 2011.);
3. direct health benefits, such as a lower prevalence of asthma in early childhood (Lovasi et al. 2008).
4. mortality reduction, and general health improvements (Maas et al. 2006; Mitchell and Popham, 2008; van de Bosh and Ode Sang, 2017);
5. flood risk reduction (Cohen et al., 2016);
6. quality of life improvement: social inclusion, safety, cultural aspects (van de Bosh and Ode Sang, 2017).

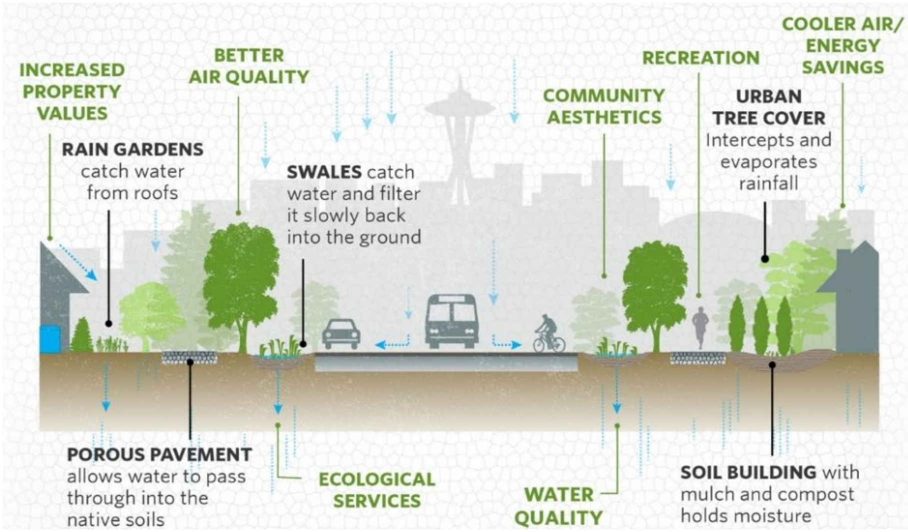


Figure 3: Ecosystem services in cities (Nature Conservancy, 2014)

The classification of urban ecosystem services can count a wide range of literature (Gómez-Baggethun et al. 2013, Gómez-Baggethun and Barton 2013; Sieber and Pons 2015, TEEB 2011; Bolund and Hunhammar 1999). Based on the primary outcomes from all these contributions, and based on the notion of ecosystem services as expressed within the Common International Classification of Ecosystem Services framework and the TEEB, an attempt is made to propose a frame to connect NBS to the ecosystem services they generate; ecosystems services, in turn, generate benefits and thus contribute to the higher-level goals previously mentioned. The frame is also based on the work done in the NBS catalogue (D1.1 of Urban GreenUP). The table below defines the ecosystem services provided by different NBS.

NBS	Ecosystem services provided
Cycle and pedestrian green route	Regulation of human diseases, Recreation and ecotourism, Social relations
Shade trees	Climate regulation, Recreation and ecotourism, Aesthetic values
Cooling trees	Climate regulation, Recreation and ecotourism, Aesthetic values
Planting and renewal urban trees	Air quality maintenance, Aesthetic values, Climate regulation Social relations, Water regulation, Sense of place, Pollination Cultural heritage values, Storm protection, Recreation and ecotourism, Inspiration
Arboreal areas around urban areas	Air quality maintenance, Aesthetic values, Climate regulation, Social relations, Water regulation, Sense of place, Pollination, Cultural heritage values, Storm protection, Recreation and ecotourism, Inspiration
Trees renaturing parking	Air quality maintenance, Pollination, Climate regulation, Storm protection, Water regulation, Aesthetic values
SUDs	Disturbance regulation, Waste treatment, Water regulation,

	Cultural, Erosion control and sediment retention
Grassed swales and water retention pounds	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control and sediment retention
SUDs for green bike lane/parking	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control and sediment retention
Rain gardens	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control, water supply
Urban catchment forestry	Sense of place, Pollination, Climate regulation, Storm protection, Water regulation, Aesthetic values, Recreation and ecotourism
Unearth water courses	Water regulation, Aesthetic Values, Erosion control, Recreation and ecotourism
Channel re-naturing	Flood protection, Air quality maintenance, Water regulation, Aesthetic and recreation values
Floodable park	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Green filter area	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment, recreational
Natural wastewater treatment	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Hard drainage pavements	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Green pavements green parking pavements	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment, recreation, ecotourism
Cycle-pedestrian green pavement	Air quality maintenance, Water regulation, Climate regulation, Water purification and waste treatment
Cool pavement	Carbon sequestration, Water purification, Nutrient retention and release
Smart soil production in climate-smart urban farming precinct	Air quality maintenance, Water regulation, Climate regulation, Water purification and waste treatment
Smart soil as substrate	Air quality maintenance, Aesthetic values, Climate regulation, Social relations, Pollination Recreation and ecotourism, Inspiration
Pollinator verges and spaces	Air quality maintenance, Aesthetic values, Pollination, Recreation and ecotourism, Inspiration
Pollinators walls/vertical	Climate regulation, Biological control, Disturbance regulation, Genetic resources, Pollination
Pollinator roofs	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Natural pollinator´s modules	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and

	ecotourism
Compacted pollinator´s modules	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Green fences	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Green noise barriers	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination
Green façade with climbing plants	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, pollination
Hydroponic green façade	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, pollination
Vertical mobile garden	Air quality maintenance, Inspiration, Water purification and waste treatment, Aesthetic values, Pollination Recreation and ecotourism
Floating gardens	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination
Green covering shelters	Water purification and waste treatment, Educational values, Climate regulation, Aesthetic values
Electro wetland	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination, Social relations, Recreation and ecotourism
Green roof	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination
Green shady structures	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination
Green filter area	Air quality maintenance, Regulation of human diseases, Climate regulation, Aesthetic values
Urban garden bio-filter	Recreation
Parklets	Air quality maintenance, Pollination, Climate regulation, Aesthetic values, Water regulation, Recreation and ecotourism, Erosion control, Pollination
Improving overall efficiency of urban wastewater treatment by using by-products	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations
Urban orchards	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations
Community composting	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations

Table 2: Ecosystem services provided by NBS at urban level, UB elaboration

However, these benefits are not valued consistently and completely. There is the need to compile a more comprehensive evidence base on the social, economic, and environmental effectiveness of NBS since the current knowledge base is rather dispersed and fragmented. “The valuation (monetary and nonmonetary) of the multiple benefits of NBS and the development of performance indicators, standards, technical and scientific reference models for NBS is necessary for their wider and systemic implementation”, as well as the availability of tailored assessment tools (EU, 2015). It is possible to adopt the approach based on the ecosystem services provided them the Ecosystem Services Approach (ESA) to evaluate the economic benefits generated through the implementation of NBS. This approach will allow identifying and valuating the generation of new, enhanced, restored flows of ecosystem services promoted by NBS, quantifying these flows in physical and monetary terms. Design and apply an innovative analytical framework to evaluate NBS based on their provision of ecosystem services explicitly tailored on the urban context will allow assessing their cost-effectiveness also concerning alternative solutions (if necessary).

In the last decade, several methodologies and tools for the valuation of ecosystem services have been developed, but just a few of them have been used for the economic valuation of the impacts and benefits generated at the local level. At this purpose, the report identifies, classifies, and explains which are the methodologies and tools for the economic valuation of ecosystem services at the urban level.

3 Ecosystem services evaluation methodologies

3.1 The Total Economic Value approach

Evaluating projects involving environmental goods and services is not an easy task. Most of these do not have a market price attached to them that can quantify their value. When performing a cost-benefit analysis, assessing costs is usually quite straightforward. For example, planting a tree, on the one hand, requires investments for the actual purchase, transport, site preparation, equipment, miscellaneous supplies, and labor costs. On the other hand, however, gauging the economic value of its benefits becomes more complicated. Ecosystem services provided by trees in an urban context include climate regulation through shading, carbon sequestration, amenity value, etc. The logic behind ecosystem valuation is to unravel the complexities of socio-ecological relationships, make explicit how human decisions would affect ecosystem service values, and to express these value changes in units (e.g., monetary) that allow for their incorporation in public decision-making processes. In literature, there are several methodologies for the evaluation of ecosystem services (System of Environmental-Economic Accounting Experimental Ecosystem Accounting - SEEA-EEA adopted by United Nations Statistical Commission, Mapping and Assessment of Ecosystems and their Services - MAES Urban developed by the European Joint Research Centre JRC, etc.). The Economics of Ecosystems and Biodiversity - TEEB (2010) requires considering the Total Economic Value (TEV) generated by ecosystem services, defined as the sum of the values of all the services that natural capital flows generate.

It should be emphasised that "total" TEV is summed across categories of values measured under marginal changes in the socio-ecological system and not over ecosystem or biodiversity (resource) units in a constant state (TEEB, 2010). Recent contributions in the field of ecosystem services have stressed the need to focus on the products (benefits) when valuing ecosystem services. This approach helps to avoid double counting of ecosystem functions, intermediate services, and final services (Boyd and Banzhaf, 2007; Fisher et al., 2009). The TEV is defined as "the sum of the values of all service flows that natural capital generates both now and, in the future, – appropriately discounted" (Pascal, et al., 2010). Through a standard unit of account – money or any market-based unit of measurement -, TEV is able to capture all elements of utility and disutility obtained from ecosystem services. Hence, this framework considers both the value that humans receive when they make use of the natural environment and the value, they attribute to it that does not originate from any exploitation. For this reason, the TEV distinguishes between use-value and non-use value (Ozdemiroglu et al., 2006), both use-value and non-use value are classified in different typologies:

Use-value is created when individuals interact with the resource, either directly or indirectly, it includes:

1. **Direct use-value** is generated when individuals in a consumptive or a non-consumptive way use resource. This kind of value is usually estimated through direct market valuation approaches such as market price-based, cost-based and production function approaches, which rely on data from actual markets in order to carry out the economic valuation;

2. **Indirect use value** indicates the benefits to individuals from ecosystem services that are supported by the resource, without actually making use of it. In this case, along with direct market valuation approaches (market price-based and cost-based ones), also revealed preferences (hedonic pricing, and the travel cost method) and stated preferences techniques (contingent valuation, and choice modelling) can be adopted.
3. **Option value**, which is the benefit from keeping open the option to use a resource in the future, without any imminent intention of using it at the current time. The existence of such value is due to the uncertainty concerning future preferences and/or the availability of the good. Since option value is based on future scenarios which are yet to happen, it can only be valued through stated preferences methods, such as contingent valuation or choice modelling.

Non-use value comes from the knowledge that the natural environment is preserved. Non-use value consists of three components:

1. **Altruistic value** stems from the awareness that contemporaries get to enjoy the natural environment.
2. **Bequest value** is given by the fact environmental good and services are passed on to future generations.
3. **Existence value** consists in the satisfaction coming from the existence of the natural environment.

In the case of the "use-value", it is possible to use direct evaluation methodologies based on the markets that reflect the actual preferences or costs for individuals (market-priced based, cost-based and production function-based approaches). In the case of "non-use value", the methodologies used for the evaluation have to be based on surrogated markets to investigate the preferences in terms of willingness to pay for a service through interviews and surveys (contingent evaluation, group evaluation, and modelling choice). The methodologies used for the evaluation/accounting of the services provided by the ecosystems are different, and often, the combination of several assessment methods is necessary. For example, the methodology of avoided costs and replacement costs are commonly used to calculate the values of regulation services such as atmospheric pollution, climate mitigation and microclimatic regulation (Sander et al., 2010). The methods most used for the evaluation of ecosystem services in urban areas are the hedonic prices, stated preferences, and contingent evaluation. (OECD, 2006).

The methodologies for the ecosystem services valuation can be dived in three groups:

1. **Direct market valuation** - use of data from real markets, which reflect actual preferences or costs for individuals;
2. **Revealed preferences** - based on the observation of individual choices in existing markets, in this case, it is said that economic agents "reveal" their preferences through options;
3. **Stated preferences** - simulation of the market and demand for ES using surveys on hypothetical variations used to estimate both the value of use and non-use;

King & Mazotta (2001), Wilson & Carpenter (1999), de Groot et al. (2006).

In the next paragraph, the table 3 summarises and describes the methodologies that can be adopted for the ecosystem services valuation. The structure defined for the methodologies description includes i) definition of the methodology; ii) values measurable; iii) approach; iv) pro and cons.

In total 15 methodologies have been analysed:

1. Direct market valuation - Market prices, Replacement costs & damage, cost avoided, Production function approaches;
2. Revealed preferences: travel costs and hedonic prices;
3. Stated preferences - Contingent valuation, Choice modelling, Deliberative monetary valuation, Questionnaire, In-depth interview, Focus group, Citizens' juries, Health-based valuation method, Q-Methodology.

3.2 The methodologies for ecosystem services valuation

	Definition	Values	Approach	Pro and cons
Market prices method	Use of directly observed prices and/or costs from actual markets related to the provision of an environmental good or service as a proxy to the value of that environmental good or service (Christie et al., 2008).	Direct and indirect use value but not non-use value. Valuation of provisioning services, or recreational value related to tourism.	These costs can take the form of opportunity costs or the cost of alternative provision.	One of its main advantage is that price data are relatively easy to obtain. However, market imperfections (e.g.: monopoly) and/or policy failures (e.g. subsidies) may distort market prices, thus failing to reflect the economic value of goods or services to society as a whole. Moreover, seasonal variations need to be taken into account. It's very likely that the value of the environmental good ends up being underestimated, considered the inability of this approach to capture non-use values. Hence, it's recommended to supplement such valuation with one based on other methods.
Replacement costs & damage cost avoided	The replacement cost method uses of the costs of replacing an environmental service as a proxy for the value of that service. The damage cost avoided method uses the costs associated with mitigation of the damage as the proxy for the value (Christie, M. et al., 2008).	Direct and indirect use value but not non-use value.	These market cost based approaches can be adopted only if certain conditions are met, more precisely: the former requires that human engineering replacement options are available and that individuals would be willing to accept this replacement, while the latter that degradation of the environment can be mitigated against.	Advantages of these methods include their straight forward and time- and resource- saving nature, thus allowing for an application even in countries where resources and technical skills are limited. However, its efficacy relies on the quality of data available, since inaccurate values can lead to a misleading appraisal of the environmental good.

Production function approaches	The production function approach focuses on the indirect relationship that may exist between a particular ecosystem service and the production of a marketed good" (Ozdemiroglu et al., 2006).	Indirect component of use value. It is best used to determine the value of those inputs that affect agriculture, forestry and fisheries.	This method considers environmental goods and services as inputs for the production of the final good, and measures their value by taking into account the changes in production process of market goods resulting from an environmental change.	This method is easily applicable in the case of single-use systems. However, with multiple-use systems understanding the link between the different elements in the production function isn't trivial. Thus, high level of econometric expertise is required. Nonetheless, because of scientific uncertainty on the various impacts of environmental inputs, the assessment of the response of production to changes in its input could be tough and lead to wrong results if not fully understood.
Travel costs	The travel cost method is a survey based technique that uses the cost incurred by individuals travelling to and gaining access to a recreation site as a proxy for the recreational value of that site (Ozdemiroglu et al., 2006).	Direct use value alone, leaving the non-use value component outside of its scope.	Costs considered are travel expenditures, entrance fees, and the value of time.	This method allows to compute recreational value of any location and is quite easy to implement. However, it tends to underestimate the actual recreational value of the site since it only considers the time and money spent on getting there. For example, individuals who have moved in the proximity of a certain natural area will reveal a small willingness to pay to visit that area according to this approach, which doesn't take into account the fact of moving there. Furthermore, the method cannot be applied in case of multifunctional trips, in which the visit to the site is not the only destination. Finally, this method is not applicable to studies in the poorest countries, where the majority of people cannot afford to travel, or, if applicable, would show a big difference in the appraisal by locals and by international tourists.

Hedonic prices	Hedonic pricing is a revealed preference method in which the value of a non-market environmental good is revealed through observation of the demand for a related complementary marketed good. (Christie et al., 2008).	The approach has the potential to isolate the effect of ecosystem services on land value.	The economic value of such factors is obtained by regressing the sale price on all those elements which affect the price.	This method relies on a large amount of high quality data on property price. This might be an issue in developing countries, where property market could be poorly defined or could be completely absent.
Contingent valuation	Contingent valuation estimates economic values by constructing a hypothetical market and asking survey respondents to directly report their willingness to pay to obtain a specific good, or willingness to accept to give up a good (Christie et al., 2008).	Direct and indirect uses, non-use value of goods, thus making it possible for total economic value to be estimated.	Respondents answer questions about their willingness to pay for certain environmental goods. These goods are a bundle of different characteristics such as quantity, quality, and ecosystem services, and attempts to evaluate the good in its entirety.	Being it in the form of a questionnaire, it allows for a high degree of flexibility in the formulation of the questions, including the valuation of scenarios that are yet to happen. It is fundamental to explain in detail the good that is going to be valued, along with the payment method, as respondents' valuation is going to be influenced by their prior knowledge, and especially by what they are told in the questionnaire itself.
Choice modelling	The choice modelling technique estimates economic values by constructing a hypothetical market for the non-market environmental good (Christie et al., 2008).	Direct and indirect uses, non-use value. The difference between the two methods is that the former asks to evaluate a single policy option, whereas the latter presents a range of levels of policy attributes.	Respondents are given a list of scenarios and they are asked to choose their preferred policy option. Based on the assumption that goods and services can be described in terms of their characteristics, this approach presents respondents with different combinations of these attributes and ask them to choose their most preferred	This method is more complex to analyse and to explain to the respondents, who may not look at the policy characteristics as a bundle but focus only on one attribute. An advantage over contingent valuation is that respondents don't have to give a price valuation of the good, but just need to select their preferred policy option, which comes with a price already attached to it.

			combination. Willingness to pay is revealed through the price attributed.	
Deliberative monetary valuation	Deliberative monetary valuation aims to combine stated preference valuation methods with elements of deliberative processes from political science (Christie et al., 2008)	The economic appraisal isn't the result of individual preferences but reflects social values.	Participating individuals form small groups to share information and raise concerns about a proposed environmental change. The procedure of quantifying environmental values in monetary terms is preceded by a dialogue or deliberation amongst the valuing agents.	A minimum level of knowledge of participants on the subject is ensured before giving the economic valuation, which turns out to be more realistic compared to that obtained with other methods. However, the presence of dominant member among the agents might lead to a decision taken only by few, thus cancelling out the benefit of the group discussion unique to this method – among the economic methods of valuation.
Questionnaire	Questionnaires are a structured process of inquiring into and recording people's perceptions on a particular topic or issue, which can be used to explore knowledge, feelings, attitudes, opinions, past experiences and expectations (Christie et al., 2008)	The method is used in conjunction with other methods because they cannot provide a direct estimation of economic value.	Questionnaires can include a wide range of question type – qualitative, quantitative, open or closed questions. They can be completed either independently by the respondent and later sent to the researcher, or on site with the supplement of interviews.	Thanks to such a high degree of adaptability, inquiry relative to the degree of investigation required can be made. However, rigor in designing the questionnaire is fundamental to ensure valid results. Indeed, one of the main issues of this method is the risk that the respondent might misinterpret the question, thus providing answers that could invalidate the whole study without the research being aware of it. When carried out via interview, there is a risk that respondents might answer based on what they think the interviewer wants to hear.
In-depth interviews	In-depth interviews aim to capture the words people use and the interpretations they make of how they value or understand something	Any kind of value can be captured via interviews.	They range from specific questions and prompts to unstructured and open-ended designs. Results are then transcribed and coded into	As with questionnaires, the way questions are asked to the respondent is crucial in order not to obtain non-pertinent results. Moreover, strict measures to ensure confidentiality might limit the interviewer capacity to inquire about

	(Christie et al., 2008)		statements, which are used for the analysis.	more sensitive issues. On the other hand, by choosing an adequate setting for the interview, the respondent will feel more at ease and encouraged to open up to the interviewer, thus allowing individuals to speak out about things they might not be comfortable talking in groups. This leads to a deeper understanding of an issue and to the creation of more effective policies, which reflect the citizens' points of view. However, this method is rather time consuming, which limits the sample size.
Focus group	Focus groups generally aim to discover the positions of participants regarding a pre-defined issue or set of related ideas and/or how participants interact during discussions (Christie et al., 2008).	Quantitative data, it is useful in collecting information on cultural and spiritual values, but any kind of value can be extracted through focus groups.	This approach is based under the assumption that social interactions among participants allow their underlying understanding and values to come to light, something that rarely happens during interviews, where the discussion is one-sided. Monetary valuation is not often the main objective of the focus group, which usually aims at choosing among several policy objectives. However, this method is often employed as a first step to eventually obtain an economic valuation.	There is no limit to the issues dealt with during focus groups, even though more complex topics might hinder the effectiveness of the discussion. Participant selection is a critical step when forming the group: for example, dominant personalities should be avoided so that decisions aren't influenced by their point of view.
Citizens' juries	Citizens' juries are used to obtain carefully deliberated and informed opinions of	All values can be captured through this method. The final	Through a process of rational discussion similar to a court scenario, decisions can be made	This method provides immediate and significant results for policy makers, given its informative and consensus building nature. The main point

	members of the public regarding a single issue or alternative scenarios” (Christie et al., 2008).	report on the findings of the jury consists of societal instead of personal values, which are usually expressed qualitatively rather than quantitatively.	based on equity and sustainability. A group of experts presents jury members the topic.	that sets it apart from focus groups is the possibility of participants to call for expert witnesses, thus ensuring a good level of understanding of the topic by the jurors. Also here the choice of participants is critical and has to ensure that diverse groups are represented. The inclusion of facilitators is recommended so that the discussion process goes smoothly. This method is more difficult to be employed in developing countries due to the lack of experts, and due to being very labour intensive. Indeed, lower literacy levels are one of the main issues that can limit this approach effectiveness by either making it impossible to form a group with adequate knowledge, or by having a representation of only the wealthiest groups, who will only think about their own benefits when addressing the issue.
Health-based valuation methods	Health-based valuations measure the combined outcomes of health related factors on the quality and length of human life” (Christie et al., 2008), and not in terms of individuals’ willingness to pay to avoid those health-related impacts.	Health benefits of policies aimed at improving environmental quality, and also the changes in people’s health as environmental degradation occurs over time.	The main techniques include: quality-adjusted life years, which looks at both the degree of improvement or deterioration in health; disability-adjusted life years, which looks at the amount of loss of healthy life due to premature death, impairment or disability; healthy-years equivalent, which involves the valuation of whole-life sequences of health states	Health based valuations methods are quite complex to perform, especially when the goal is to value whole health profiles instead of focusing on a health state at a specific time. Moreover, analysing individuals belonging to different groups in the demographic spectrum according to their characteristics - age, quality of life - might lead to erroneous estimates, as different values are attached to these groups in terms of mortality reduction. The method might be useful in developing countries, where expected life span is much lower than in the developed world and thus studies assessing

			which can change over time.	benefits in terms of increased life expectancy would be extremely important.
Q-Methodology	Q-methodology aims to classify beliefs and preferences of a group of people" (Christie et al., 2008).	Any kind of value can be captured (people's understanding and perception of environmental problems and their solutions over quantitative estimations).	The method is made up of fours steps. i) Collection of a series of statements about a specific issue from qualitative data sources. ii) Reduction of the sample of statement is reduced to 20-50 of them. iii) Definition of a rank. iv) Factor analysis which identifies the key factors that best represent the responses of a specific individual in relationship to the other participants' ones.	An advantage of Q-methodology is that it doesn't require a large sample size. It also allows to sort qualitative views and values of individuals and to group them into quantitative dimensions. Statements can even be replaced with images to make the ranking task easier for individuals. However, results obtained with this method are almost impossible to transfer to other contexts because the dimensions obtained through factors analysis put in relation individual values with those of the other participants. It is also a time-consuming and skill-intensive technique.
Delphi survey	Delphi surveys elicit and refine group judgements of a set of experts" (Christie et al., 2008) – usually 10.	Any type of value can be assessed.	Experts are given the opportunity to tackle the issue over several iterations so that they are allowed to reconsider their views after seeing the responses from the others until a consensus is reached.	Since it is based on collective knowledge of experts, results are usually very solid. Therefore, this method provides valuable and especially reliable information for policy makers. Given that participants stay anonymous, it allows probing for more sensitive topics and allows participants to express their point of view freely. This might hinder the application of Delphi surveys in developing countries, where both the lack of resources and expertise are huge obstacles.

Table 3: Methodologies for ecosystem services valuation

As previously described, the methodologies can be used to measure "use value" and "non-use value" and the related ecosystem services associated. To better clarify the linkages between the TEV approach (use and non-use value) the associated ecosystem services and the economic valuation approaches that can be adopted, an interpretative framework has been created.

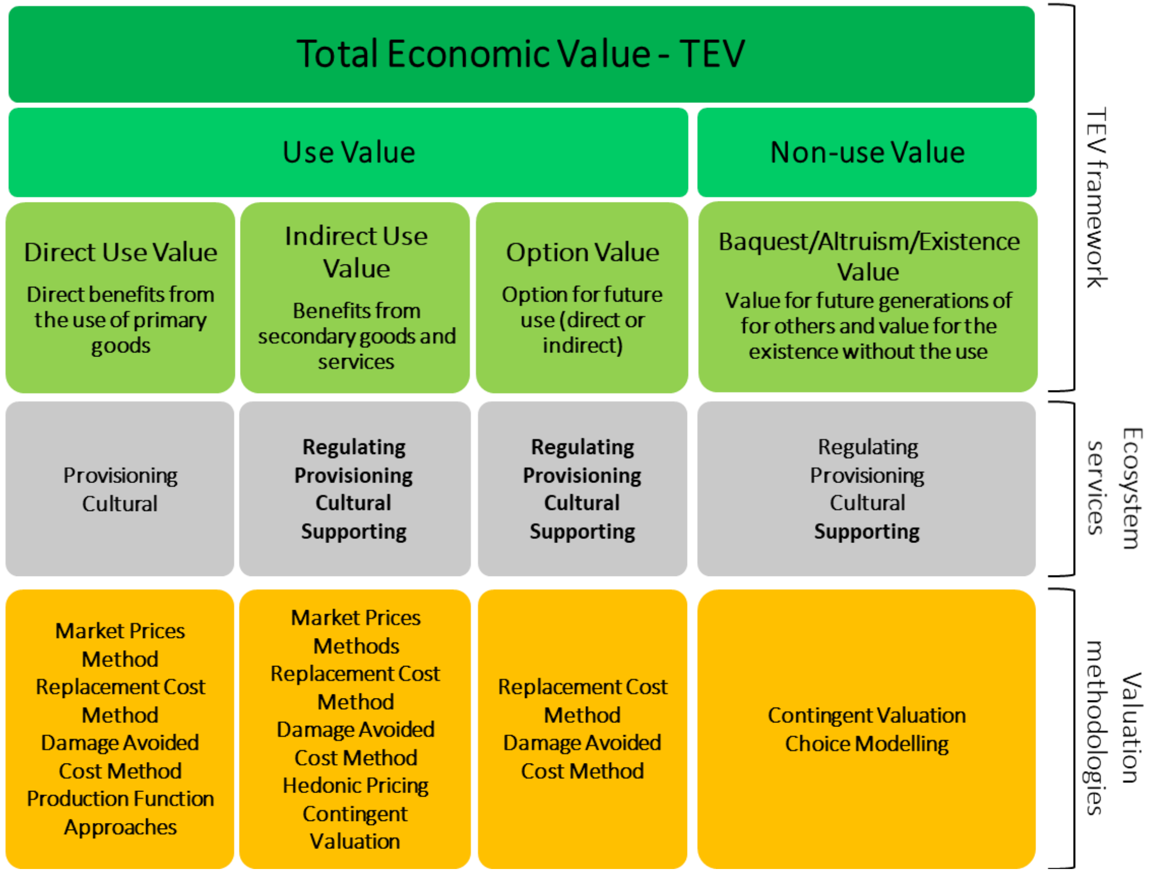


Figure 4: Methodologies for the estimation of the different types of values. Adapted from Pascual, U. et al., 2010 and EC, 2013.

3.3 The ecosystem services valuation at urban level: case studies

The methodologies analysed can be applied at different territorial scales (national, regional, or urban level). To identify which are the most suitable methodologies for the economic valuation of ecosystem services at the urban scale, a review of the literature and case studies has been performed. By using Scopus, more than 70 papers have been considered, but just a few of them reported quantitative results related the economic valuation. First of all, the methodology name was inserted as keyword, followed by “ecosystem service”, “[economic] valuation”, and “urban” in this order. If the search query provided no results, one or more keyword were removed, starting from the last one. Sometimes, references to suitable papers were found within studies that carried out a systematic review of the evaluation of ecosystem services. In total, 37 papers (and case studies) has been included in this report. Here the full list of the methodologies individuated:

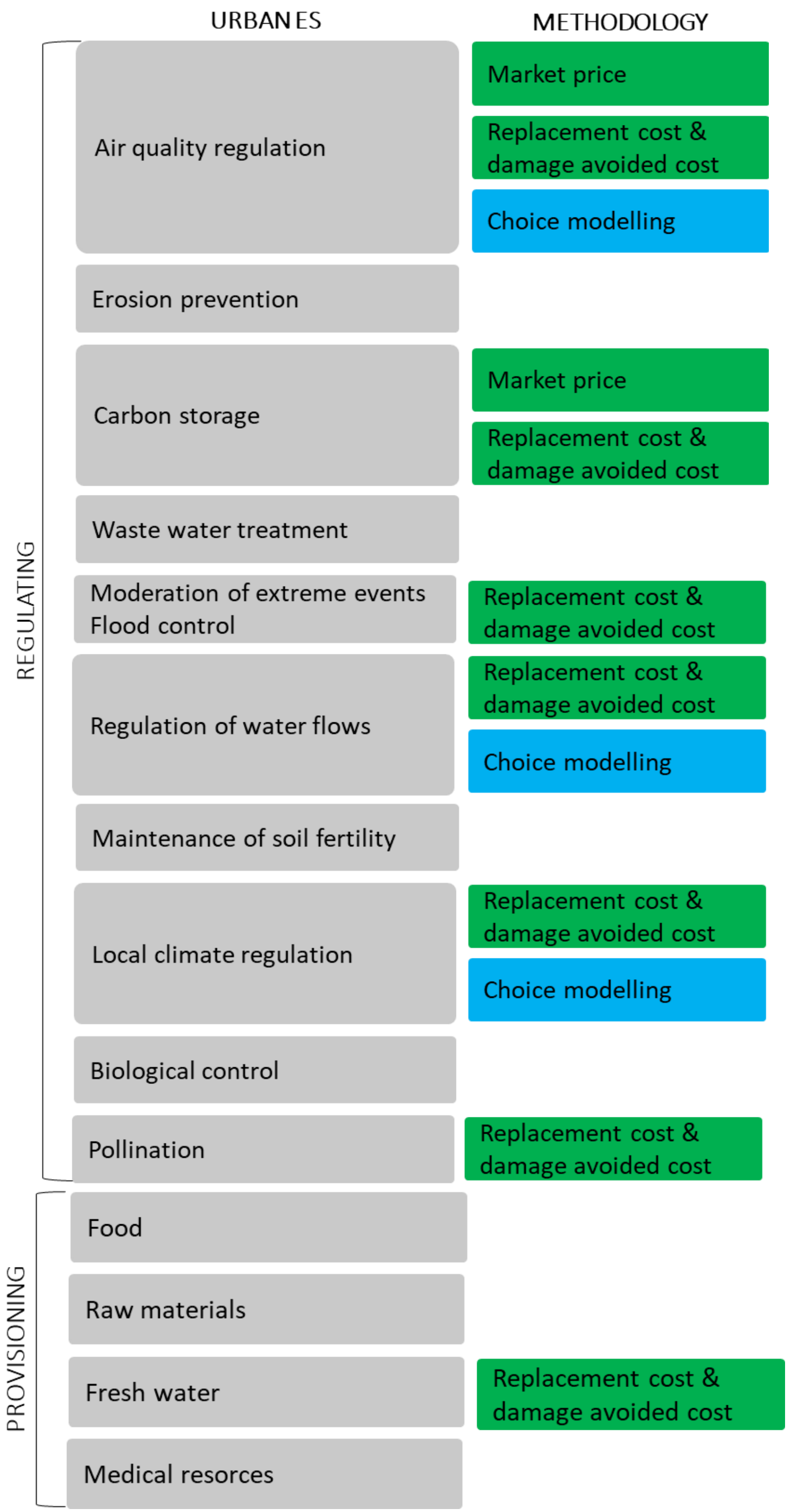
Methodology group	Valuation methodology
Direct market valuation	Market prices Replacement cost Damage cost avoided
Revealed preferences	Travel costs Hedonic prices
Stated preferences	Contingent valuation Choice modelling Deliberative monetary valuation Questionnaires In-depth interviews Q methodology

Table 4: Methodologies for ecosystem services valuation at urban level

Through the 37 papers individuated 18 ecosystem services has been valuated. The ecosystem services cover only three out if four categories: regulating, provisioning, and cultural. In light of this, it must be underlined that the ecosystem services under the supporting category are still not been valuated at the urban level.

The case studies have been collected and categorised based on a standard framework to identify the economic valuation methodology quickly, and the ecosystem service valuated. Other variables have been taken in consideration for the case studies classification: the methodology used, the study location, the year of evaluation of the ecosystem service, the provider of ecosystem service, the ecosystem service under consideration, the necessary data in order to perform the analysis, the final economic evaluation, and those who benefit from such ecosystem service. (see Annex A1).

In this way, based on the literature review analysis, an interpretative framework linking ecosystem services and the various methodologies available to evaluate them at the urban level has been created. Methodologies in green boxes belong to the direct market valuation approaches, those in purple boxes to the revealed preferences category, and those in light blue boxes to the stated preferences methods. The figure below summarised the framework defined for the evaluation of ecosystem services at the urban level based on the ecosystem services approach.



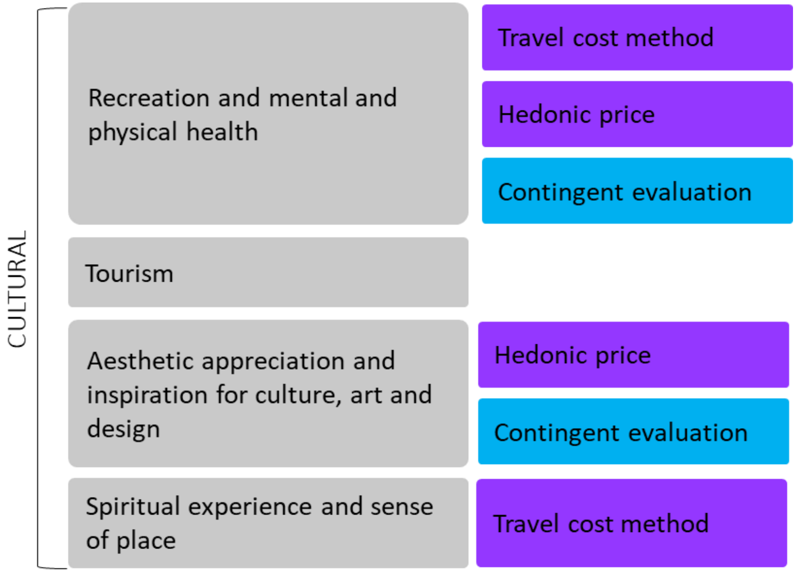


Figure 5: Ecosystem services and valuation methodologies literature review and case studies

4 Ecosystem services evaluation tools

There is a range of tools available to assist decision-makers in the integration of ecosystems and their services into policy and planning decisions. In particular, in the last decade, different tools related to the economic valuation for the ecosystem services have been developed. In fact, following the increased awareness and acknowledgment of nature's role in supporting human well-being, a plethora of tools for measuring, modelling, and valuing ecosystem services have been developed in recent years. For practitioners, selecting an appropriate tool or suite of tools for measuring and modelling ecosystem services can be confusing. Tools are created for different purposes, produce various outputs, and have different requirements in terms of time, data, and specialised expertise. Different papers and reports for the valuation tools classification and analysis have been created.

Based on the literature review, a repository of the existing tools for the economic valuation of ecosystem services has been defined. The tools have been classified based on several criteria:

1. Function – definition of the tool and ecosystem services that can be measured through the application of the tool;
2. Approach – the methodology for the economic valuation of the ecosystem services and data need for the valuation;
3. Scale – identification of the scale at which is possible to carry out the valuation (urban, local, landscape, etc.).

In total, 38 tools have been individuated and reported in Annex A2. The tools individuated can be adopted for the valuation of ecosystem services at different territorial scales. Just a few of them can be used for the valuation of ecosystem services at the urban level. An analysis of the existing literature on the ecosystem services valuation has been performed to understand the tools' potential and effectiveness. The review does not aim to include all tools that have been developed for assessing ES: more than 60 papers have been analysed. The research has been performed using Scopus, and the case study repositories developed by other EU projects focused on NBS (Naturvation, ThinkNature, Oppla). First of all, the tool name was inserted as keyword followed by “economic valuation”, “ecosystem service”, and “urban” in this order. If the search query provided no results, one or more keywords were removed, starting from the last one. Several case studies were found on the tool website. We focus on those tools that are freely available, can be applied anywhere in different contexts, and which have demonstrated applications in sites.

In total, 18 case studies have been identified. In the analysis of the tools and case studies, different variables have been taken into account:

1. Location and year: these two variables have been taken into consideration to understand the variability of the ecosystem valuation based on the site and time.
2. Ecosystem services: this variable has been analysed to understand which ecosystem services can be valuated by using a specific tool;
3. Input/data: the data that has been used for the valuation has been reported to facilitate the understanding of the tool functioning;

4. Economic Valuation: in some cases, the tools analysed do not include a methodology for the economic valuation, but just the impact assessment of the ecosystem services. In these cases, the economic valuation has been performed in a second step.
5. Methodology used: this variable has been included to understand if the tools analysed incorporates a specific valuation methodology.
6. References: the source of the data used for the case study analysis have been reported to allow and facilitate the consultation.

The table below summarises the case studies analysed. The case studies have been reported in Annex A3 of the report.

Tool	Location/year	Ecosystem Services valuated
APST (Adaptation Planning Support Toolbox)	Utrecht The Netherlands 2005	Water quantity regulation (reduction of run off); Heat stress reduction
ARIES (ARtificial Intelligence for Ecosystem Services)	Puget Sound USA 2006	Flood regulation for developed land in 100-year floodplain; Homeowner proximity to open space; Scenic view sheds for homeowners
BeST (Benefits of SuDS Tool)	Zwolle The Netherlands 2007	Cultural (health, education, amenity); regulating (climate, carbon, flooding); and supporting (biodiversity)
CITYgreen	Wellington 2005	Air pollution removal; Water quality (runoff)
Co$ting Nature	Southern Ontario Canada 2017	Water provisioning and supply; water quality; carbon sequestration; carbon storage; flood regulation; nature-based tourism (including recreational and aesthetic value)
EcoServ-GIS	Cumbernauld UK N.A.	Air purification; carbon; local climate; noise regulation; pollination; water purification; accessible nature; education; green travel
ESII (Ecosystem services identification and inventory tool)	Kanawha River USA N.A.	Water provisioning; water quality control; erosion control; visual aesthetics
ESTIMAP	Oslo Norway 2016	Pollination
GI-Val (Green Infrastructure Valuation Toolkit)	St Helens UK 2005	Climate change adaptation & mitigation; Water management & flood alleviation; Health & well-being; Labour productivity; Tourism; Recreation & leisure; Biodiversity; Land management
HEAT (Health Economic Assessment Tools)	Kuopio Finland N.A.	Health benefits
InVEST (Integrated Valuation of Ecosystem Services and Trade-offs)	3 towns (combined urban areas) UK	Carbon storage; sediment erosion; pollination

	2007-2010	
i-Tree (previously UFORE)	10 cities USA 1996-1999	Carbon sequestration
NCPT (The Natural Capital Planning Tool)	Birmingham UK 2016	Harvested products; biodiversity; Aesthetic values; recreation; Water quality regulation; Flood risk regulation; air quality regulation; local climate regulation; global climate regulation; soil contamination
ORVal	West Norwich UK N.A	Recreational value
QUICKScan	Glenlivet UK N.A	Timber provision, wader bird habitat provision, recreational fishing, recreational hiking and cattle grazing
SWC (EPA's National Storm water Calculator)	12 cities USA 2010-2015	Water runoff
SWMM (Storm Water Management Model)	Genova Italy 2007-2008	Storm water run off
The National Green Value Calculator	Houston N.A.	Run off reduction

Table 5: Tools for ecosystem services valuation at urban level

The analysis performed highlights that the economic valuation of the ecosystem services at the urban level represents still an issue, in particular for the cultural ecosystem services. In the majority of the case study analysed the ecosystem services that have been evaluated are related to the quality of the air, carbon sequestration, temperature regulation and mitigation of the heat island effect, water management, and flood regulation. This can be attributed at:

- Data availability: the literature and the data available related to some ecosystem services (e.g., cultural) are more challenging to collect and to analyse since they are related to the preferences of the individuals. The data associated with regulating, supporting, and provisioning services are much easier to monitor and collect.
- Tools development: in some of the case studies, the tools analysed are not able to measure the cultural services provided by green solutions at the urban level.

Several guidelines have been defined and reported in the next section, taking into account the outcomes of the analyses performed on the methodologies and tools for the ecosystem services valuation at the urban level.

5 Guidelines for ecosystem services valuation at urban level

The monetary valuation of NBS based on the Ecosystem Services Assessment can be carried out using different instruments, including innovative tools and methodologies. As already highlighted the approach based on the ecosystem services valuation will allow for catching all benefits provided by NBS and for demonstrating the cost-effectiveness of these solutions at the urban level. Based on the analysis that has been carried out the most suitable methodologies and tools for the ecosystem valuation at the urban level have been individuated and reported in the Annex A1 and Annex A2 of the report. To facilitate the use of this report and to perform the economic valuation of NBS at the urban scale, some guidelines have been defined.

1. **Definition of the purpose and objective of the valuation.**
   Defining the purpose and objectives should be the starting point for carrying out an ES assessment, as this informs whether it makes sense to undertake an assessment in the first place, the scope and depth of the assessment, and the selection of the most appropriate tool(s). In general, an ES assessment of one or more sites is worthwhile when there is a need for additional ES understanding, there are clear objectives for the assessment, and there is a clear plan as to how the results will be used to support site conservation or management. It may not make sense to undertake an in-depth ES assessment if, for example, it would divert scarce resources from other more pressing needs such as conservation activities, site management, and biodiversity assessments, or it would not provide clear added value to site management. Monetary valuation of ES can sometimes be in conflict with conservation objectives if the economic values associated with conservation are not as high as alternative land uses in the short term (Schröter et al., 2014). This does not mean that the site should be converted, but that the conservation value needs to be assessed from a non-monetary perspective, such as globally significant biodiversity values, irreplaceable cultural values or relational values (Chan et al., 2016). Also, certain ES (such as cultural heritage) are difficult to assess in monetary terms and may be better evaluated using non-monetary measures. It is important to keep these risks and limitations in mind and to be strategic about when and how to undertake an ES assessment. The figure below represents a complete list of the purpose and objective of the valuation (IUCN, 2018).

Public/policy support	
Provide additional evidence and justification for the importance of conserving a particular site	Government agencies, policy and decision makers, local stakeholders, businesses, donors
Foster local awareness of the ES provided by a particular site	Local communities, Indigenous and traditional people, local decision makers
Build support for the conservation of multiple sites through increased understanding of their wide range of benefits	Government agencies and ministries, civil society
Link ES contributed by all sites in a country to international or national sustainability goals and national policies (e.g. Sustainable Development Goals)	Government, international community
Site management	
Establish the baseline of ES provided by a site to enable monitoring of changes and support management planning	Site managers and others responsible for monitoring sites
Reveal synergies and possible trade-offs between ES and/or ES and conservation objectives to identify management options for the site and better define conservation objectives	Site managers, local stakeholders
Develop, implement and update management strategies for the site, building on the understanding of ES (e.g. integration of ES into site's management plan or developing a business plan for the site)	Site managers, local communities, Indigenous and traditional people, conservation organisations, businesses
Human well-being	
Ensure a good understanding of the ES values that are important to resident, local and more distant stakeholders	Managers, communities, companies using ecosystem services, municipalities
Assess compensation options to resident and local stakeholders for ES forgone as a result of biodiversity conservation, to contribute to discussions about Free Prior and Informed Consent, conflict resolution, etc.	Land and water managers, communities living in or near the site
Planning	
Support spatial and strategic conservation planning and investment by identifying areas of particular importance for ES	Government agencies, conservation organisations, donors
Assess potential consequences of different sectoral (e.g. agriculture, hydropower, infrastructure) decisions and policies on ES delivered by sites (scenario comparison)	Government agencies and ministries, businesses, landowners, resource rights holders, local communities, multilateral financial institutions
Assess potential consequences of climate change scenarios on ES provided by a site	Government agencies and ministries, conservation organisations, landowners, Indigenous and traditional people, businesses, communities living in or near a site, managers
Integrate ES delivered by sites into land-/water-/resource-use planning at regional, national or sub-national scales (e.g. Strategic Environmental Assessment), understand implications for management of surrounding areas to improve flows from or resilience of site ES	Government agencies and ministries, conservation organisations
Private sector engagement	
Help businesses manage risks and meet their social and environmental responsibility targets, by identifying possible impacts on ES and beneficiaries (e.g. Environmental Impact Assessments, corporate sustainability assessments)	Businesses, consultants or conservation organisations working with businesses, government agencies, eco-certification assessors
Provide incentives for businesses to engage in the conservation of sites by demonstrating the dependence of the businesses on ES provided by sites (e.g. public-private funding schemes, in-kind support, branding)	Businesses, site managers, local communities, Indigenous and traditional people, consultants or conservation organisations working with businesses, government agencies, eco-certification assessors
Funding and investment	
Attract government and donor investment from other sectors concerned with conservation of ES (e.g. water management, public health, national security) and/or donors interested in sustainable development	Government ministries, development agencies and organisations
Support the development of new sustainable finance mechanisms for conservation of the sites, such as Payments for Ecosystem Services (PES) or carbon financing such as Reduced Emissions from Deforestation and Forest Degradation (REDD+)	Businesses, public and private investors, government agencies, conservation organisations, local communities
Knowledge generation	
Inform research on ES provided by sites locally, nationally, regionally or globally	Academics, students, conservation organisations, research organisations
Inform research on the synergies and trade-offs between conserving biodiversity and ES, between different ES, and between different stakeholders	Academics, students, conservation organisations, research organisations

2. **NBS selection and definition.**
Cities are facing different problems that can be solved through the implementation of NBS and the enhancement of urban ecosystems. Each NBS will generate several benefits, but to exploit the NBS potential, it is fundamental to carry out a preliminary analysis of the specific territorial issues and then define the NBS to be implemented. In this way, it will be possible to determine cost-efficient NBS.
3. **Individuation of the impacts generated through the implementation of NBS.**
To measure the economic value of NBS, it is fundamental to identify all the benefits generated by them. The NBS catalogue (D1.1) can be used to detect the ecosystem services produced by different NBS. Furthermore, also, table 1.1 can be used for the identification of the ecosystem services generated.
4. **Identification of the ecosystem services generated**
A scoping phase can provide an overall picture of the full range of ES provided by a site or sites and the associated beneficiaries at local, regional, national, and global levels. While only some of these ES might be selected for further assessment, scoping helps to ensure that all benefits are identified and accounted for. It can also help to draw attention to benefits that might become more important in the future, for example, due to climate change or resource scarcity. Scoping also allows the assessment of site ES to be placed in a broader socio-economic context, helping to ensure the correct use and targeting of results and can help identify different rights holders and stakeholders that should be considered or engaged in the assessment process. The definition for the ecosystem services that will be valuated is fundamental for the selection of the methodology or tool to be adopted (see figure 3 or table 1).
5. **Selection of the methodology or tool for the ecosystem services monetary valuation**
Based on the outcomes of the previous steps, it will be possible to identify a specific methodology or tool to perform the valuation of the ecosystem services and the NBS implemented. The methodologies and the tools have been classified and reported in the Annex A1 and Annex A2 (see also figure 5).
6. **Qualitative or quantitative valuation.**
Depending on the question and context for the ES assessment, qualitative or quantitative methods may be preferred. Qualitative assessment is important for scoping, identification of relevant services, identifying which groups of stakeholders benefit from particular services, and prioritising sites for more in-depth research. Qualitative assessments also have benefits in bringing together stakeholders to think about ES values and implications of management decisions. Furthermore, qualitative methods can be used to identify sociocultural values. However, if there is interest in establishing policies or measures to protect ecosystems (e.g., payments for ecosystem services) or to finance NBS, those benefits might need to be quantified to determine more accurately how much of a given service is being produced by a given site and how the delivery of that service is affected by management. Quantitative measurement or spatial modelling of ES, such as monitoring data on a particular ES, can be particularly helpful if a site is under significant pressure of conversion to an alternative land or water use scenario. It can also highlight trade-offs and synergies between alternative resource use strategies and therefore inform management decisions. However, combining qualitative and quantitative analysis can be

beneficial at all stages of an ES assessment. Although the purpose of the assessment should drive the choice of qualitative and/or quantitative methods, the capacity and resources available to the assessment team is always a factor. In general, quantitative ES assessments require more technical expertise, such as the ability to collect and analyse biophysical data on ecosystem services or conduct spatial analyses using GIS-based modelling software. The time and skills required for conducting a rigorous qualitative assessment should not be underestimated, however. For example, performing a series of workshops with the full suite of stakeholders associated with a PA; or conducting an extensive, well-designed survey to assess ES provided by a natural WHS both require time, resources and specific skills such as stakeholder analysis, workshop facilitation, survey design, and data compilation and analysis. The methods chosen should be informed by the scoping phase and primary objectives of the ES assessment.

7. **Monitoring strategy**

   The monitoring strategy is fundamental to allow the measurement of the impacts generated by NBS and to assess the ecosystem services provided by them. Different approaches to the impact assessment of NBS are available (e.g., KPIs), and they are fundamental to monitor the status of the variables that want to be valuated. Through the definition of a monitoring strategy, it will be possible to define a baseline and to compare it after the implementation of the NBS.

8. **Stakeholders' engagement.**

   All ES assessment processes should involve some level of stakeholder engagement. Stakeholders can help identify the relevant ES to assess at a site; provide sources of data, information, and knowledge that can result in a more robust assessment; help to validate ES assessment results and ensure that assessment results are actually used for management or policy decisions. Including stakeholders from the beginning also helps build trust and ensure that the people or groups who will ultimately be responsible for the management of the site will accept the information produced during the assessment process.

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Appendix: Operational guidelines for the monetary valuation of NBS in cities

The “Operational guidelines for the monetary valuation of NBS in cities” aims to guide local administrators in the economic valuation of the benefits generated by NBS at the urban level. The approach used for the valuation of the benefits provided by the NBS is based on the ecosystem services (ES).

The guidelines consist of the following 5 steps:

1. **Identification of the ES provided by NBS**
2. **Identification of the methodology:**
   - **2.1 Ex-ante evaluation**
   - **2.2 Ex-post evaluation**
3. **Definition of the monitoring strategy**
4. **Identification of the stakeholders to involve**
5. **Identification of the tools to adopt**

1 Identification of the ES provided by NBS

Given that NBS provide several ES, the public officer needs to identify the ES generated by the planned NBS. Table 1 matches all the NBS currently being implemented in the 3 cities of the Urban GreenUP project with the ES provided by them. A more detailed list of ES generated by each NBS can be found in the deliverable D1.1 of URBAN GreenUP project.

NBS	Ecosystem services provided
Cycle and pedestrian green route	Regulation of human diseases, Recreation and ecotourism, Social relations

Shade trees	Climate regulation, Recreation and ecotourism, Aesthetic values
Cooling trees	Climate regulation, Recreation and ecotourism, Aesthetic values
Planting and renewal urban trees	Air quality maintenance, Aesthetic values, Climate regulation, Social relations, Water regulation, Sense of place, Pollination, Cultural heritage values, Storm protection, Recreation and ecotourism, Inspiration
Arboreal areas around urban areas	Air quality maintenance, Aesthetic values, Climate regulation, Social relations, Water regulation, Sense of place, Pollination, Cultural heritage values, Storm protection, Recreation and ecotourism, Inspiration
Trees renaturing parking	Air quality maintenance, Pollination, Climate regulation, Storm protection, Water regulation, Aesthetic values
SUDs	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control and sediment retention
Grassed swales and water retention pounds	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control and sediment retention
SUDs for green bike lane/parking	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control and sediment retention
Rain gardens	Disturbance regulation, Waste treatment, Water regulation, Cultural, Erosion control, water supply
Urban catchment forestry	Sense of place, Pollination, Climate regulation, Storm protection, Water regulation, Aesthetic values, Recreation and ecotourism
Unearth water courses	Water regulation, Aesthetic Values, Erosion control, Recreation and ecotourism
Channel re-naturing	Flood protection, Air quality maintenance, Water regulation, Aesthetic and recreation values

Floodable park	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Green filter area	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment, recreational
Natural wastewater treatment	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Hard drainage pavements	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment
Green pavements green parking pavements	Water regulation, Erosion control and sediment retention, Water supply, Waste treatment, recreation, ecotourism
Cycle-pedestrian green pavement	Air quality maintenance, Water regulation, Climate regulation, Water purification and waste treatment
Cool pavement	Carbon sequestration, Water purification, Nutrient retention and release
Smart soil production in climate-smart urban farming precinct	Air quality maintenance, Water regulation, Climate regulation, Water purification and waste treatment
Smart soil as substrate	Air quality maintenance, Aesthetic values, Climate regulation, Social relations, Pollination Recreation and ecotourism, Inspiration
Pollinator verges and spaces	Air quality maintenance, Aesthetic values, Pollination, Recreation and ecotourism, Inspiration
Pollinators walls/vertical	Climate regulation, Biological control, Disturbance regulation, Genetic resources, Pollination

Pollinator roofs	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Natural pollinator´s modules	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Compacted pollinator´s modules	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Green fences	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination, Recreation and ecotourism
Green noise barriers	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, Pollination
Green façade with climbing plants	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, pollination
Hydroponic green façade	Air quality maintenance, Educational values, Climate regulation, Aesthetic values, pollination
Vertical mobile garden	Air quality maintenance, Inspiration, Water purification and waste treatment, Aesthetic values, Pollination Recreation and ecotourism
Floating gardens	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination
Green covering shelters	Water purification and waste treatment, Educational values, Climate regulation, Aesthetic values
Electro wetland	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination, Social relations, Recreation and ecotourism
Green roof	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination
Green shady structures	Air quality maintenance, Inspiration, Climate regulation, Aesthetic values, Pollination

Green filter area	Air quality maintenance, Regulation of human diseases, Climate regulation, Aesthetic values
Urban garden bio-filter	Recreation
Parklets	Air quality maintenance, Pollination, Climate regulation, Aesthetic values, Water regulation, Recreation and ecotourism, Erosion control, Pollination
Improving overall efficiency of urban wastewater treatment by using by-products	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations
Urban orchards	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations
Community composting	Food and fibre, Sense of place, Water regulation, Recreation and ecotourism, Social relations

Table 1: Ecosystem services provided by NBS at urban level, UB elaboration

2. Identification of the methodology

The second step of the operational guidelines consist in the selection of the economic valuation methodology to adopt. Based on the literature it is possible to use different methodologies based on the typology of ES that have to be valued. At the same time, it is possible to perform the valuation of the ecosystem services provided by NBS before (ex-ante) and after (ex-post) implementing it.

2.1. Ex-ante valuation

For the ex-ante valuation, the recommended methodology is benefit transfer, which consists of 4 steps: i) identification of existing studies that value the same benefits; ii) assessment of the transferability of the values; iii) evaluation of the quality of the studies; iv) adjustment of the values. These steps are summarized and explained in Table 2.

STEP 1: identification of existing studies or values that can be used for the transfer, where the benefits being valued in these studies are the same or similar to those required
STEP 2: decide whether the existing values are transferable. The existing values or studies would be valuated based on several criteria, including comparability of service delivered and of the characteristics of the population surveyed
STEP 3: evaluate the quality of studies to be transferred. The better the quality of the initial study, the more accurate and useful the transferred value will be
STEP 4: adjust the existing values to better reflect the values for the service under consideration, using whatever information is available and relevant

Table 2: Application of the benefits transfer method (LIFE N2K Wales, 2015)

In deliverable 7.3 of URBAN GreenUP project an ex-ante economic valuation of the benefits provided in three cities (Liverpool, Izmir and Valladolid) has been performed. The values that have been used to apply the benefit transfer technique have been reported here in Table 3 and they can be used to replicate the ex-ante valuation in other cities.

	PROVISIONING	REGULATION									CULTURAL		
NBS	food production	carbon sequestration and storage	air quality regulation	water regulation	climate regulation	storm water protection	energy saivings	UIH effect reduction	noise reduction	recreation and tourism	aesthetic value	sense of place	all
Urban gardens and parks		^1,11 €	0,05 - 0,39 €	^ 11 €	^ 0,07 €	^ 0,167 €				0,95 €	81,50 €		
												0,003 - 0,022 €	
										4,90 €			
Urban forest		1,17 €	8,17 €	55,20 €	3,12 €					0,95 €	81,50 €		
			0,05 €			0,17 €						0,003 - 0,022 €	
			^ 0,05 - 0,39							4,90 €			
					3,00 €								
		1,11 €	*11,98		0,07 €			51,3 - 69,34 €					
		4,53 - 14,25 €	1,68 - 14,50		9,05 - 22,6								
Rain garden				13,76 €		^ 0,167 €							
Permeable pavement				11,00 €		^ 0,167 €							
Vegetated swale				11,00 €		^ 0,167 €							
Green roof		0,56 - 0,98 €	0,57 - 0,94 €	8,25 €			1,24 - 7,97 €	3,00 - 6,73 €			^ 2,74 €		
Green walls		^ 0,56 - 0,98 €	^ 0,57 - 0,94 €					^ 3,00 - 6,73 €	2,65 €		2,74 €		
							15,83 €						
Urban orchards	4,06 €			^ 11 €		^ 0,167 €				^ 0,95 - 4,90 €			
Technological green													0,50 - 14,92 €
Cycle path										^ 0,95 - 4,90 €			

m2/year	* the value has been excluded from the valuation since the case study is located in China and the air pollution levels are extremely different from EU cities
tree/year	^ the value refers to the ecosystem provided by another NBS, but it has been transferred given the characteristics of the NBS considered and the ecosystem provided

Table 3: NBS and ecosystem services values for the benefit transfer

The matrix includes the values detected in the literature. In some cases, the value of a specific ecosystem service is represented by a single value since only a case study was found for that particular ecosystem service and NBS. In other cases, the values of the ecosystems are represented by ranges since more than one value has been found in the literature. For some NBS (Urban forest and Urban gardens and parks) the values individuated have different units of measurement: m2/year and tree/year. In those cases, to avoid the double counting issue, only the value referred at the trees has been used to perform the ex-ante valuation, since the value is more reliable.

CASE STUDY: Application of the benefit transfer methodology to the city of Valladolid in the URBAN GreenUP project

For the ex-ante valuation, the benefit transfer methodology has been applied to the cities of Valladolid, Izmir, and Liverpool. Additional information with respect to the methodology can be found in deliverable 7.3.

After carrying out the literature review, the public officer needs to analyze the values found in the case studies. The variability in the methodologies and tools applied for the valuation of ES is likely to produce different values for each ES. For this reason, when possible, a range of values has to be defined for each ES by using the minimum and the maximum value detected.

The economic values have to be converted in a common currency, in this case euros. Afterwards, the value of the ecosystem services generated per single unit of measure can be calculated. When it comes to NBS, the values ought to be expressed either in *euro/m2/year* or *euro/tree/year*. The table below shows the ex-ante economic valuation for the city of Valladolid.

NBS	ES	Economic value per year
Cycle and pedestrian green route	Recreation and tourism	3.173 € - 16.366 €
Urban carbon sink	Carbon sequestration and storage, air quality regulation, water regulation, climate regulation, storm water protection, UIH effect reduction, recreation and tourism, aesthetic value, sense of place	1.245.140 € - 1.737.521 €
Green resting areas	Recreation and tourism, sense of place	286 € - 1.477 €
Trees re-naturing parking	Carbon sequestration and storage, air quality regulation, water regulation, climate regulation, recreation and tourism, aesthetic value, sense of place	8.780 € - 13.875 €
Planting and renewal urban trees (including	Carbon sequestration and storage, air quality	74.520 € - 94.115 €

urban catchment forestry)	regulation, water regulation, climate regulation, recreation and tourism, aesthetic value, sense of place	
Mobile gardens (forest)	All	500 € - 14.920 €
Cooling and shade trees	Carbon sequestration and storage, air quality regulation, water regulation, climate regulation, storm water protection, UIH effect reduction, recreation and tourism, aesthetic value, sense of place	44.712 € - 56.469 €
Pollinator systems (including smart soil and green fences)	N.A.	N.A.
Vertical gardens, green noise barriers and green walls	Energy savings, noise reduction, aesthetic value	10.546 € - 12.426 €
Green roof and green covering shelters	Carbon sequestration, air quality, water regulation, climate regulation, storm water protection, energy savings, UIH effect reduction, aesthetic value	21.257 € - 25.949 €
Electro wetland	All	25 € - 746 €
Green shady structures	All	119 € - 3.536 €
Urban garden bio-filter	All	5 € - 149 €

Urban farming	Food production, water regulation, storm water protection, recreation and tourism	1.618 € - 2.013 €
Floodable parks	N.A.	N.A.
Natural wastewater treatment (including green filter area)	All	158.011 € - 222.014 €
SUDs	Water regulation, storm water protection	18.620 €
Rain gardens	Water regulation, storm water protection	13.760 €

Table 5: Ex-ante economic valuation of the NBS implemented in Valladolid

2.2. Ex-post valuation

The performance of the ex-post valuation depends on the ES that have to be valued. There are 6 main methodologies, each suited to valuing a different array of values and ES. Table 4 summarises and describes the methodologies that can be adopted for the ecosystem services valuation. The structure defined for the methodologies description includes i) definition of the methodology; ii) ES measurable; iii) pro and cons. This will allow to easily detect the most suitable methodology that can be adopted for the valuation of the different typologies of ES provided by NBS at the urban level.

Methodology	Definition	ES	Pros	Cons

Market Price methods **(Christie et al., 2008)**	"Market-price methods utilize directly observed prices and/or costs from actual markets related to the provision of an environmental good or service as a proxy to the value of those goods."	Provisioning, regulating and cultural services.	Price data are easy to obtain.	The value of goods and services can be under-estimated due to market imperfections. The value of the natural resource can be underestimated, considering the inability to capture non-use values.
Replacement cost & Damage cost avoided **(Pearce and Turner, 1990)**	"The replacement cost method measures the potential expenditures in replacing/restoring the function that is lost. The damage cost avoided method measures the costs that would be incurred if a specific environmental function were not present."	Regulating services.	Straight forward and time- and resource- saving nature, thus allowing for an application even in countries where resources and technical skills are limited.	The methodology relies on the quality of data available, since inaccurate values can lead to a misleading appraisal of the natural resource.
Travel cost method **(Ozdemiroglu et al., 2006)**	"The travel cost method is a survey-based technique that uses the cost incurred by individuals travelling to and gaining access to a recreation site as a proxy for the recreational value of that site."	Cultural services.	It allows computing recreational value of any location and is quite easy to implement.	It tends to underestimate the recreational value of the site since it only considers the time and money spent on getting there. The method cannot be applied in case of multifunctional trips, in which the visit to the site is not the only destination. It is not applicable to studies in the poorest countries, where the majority of people cannot afford to travel.
Hedonic pricing **(Pearce and Turner, 1990)**	"Hedonic pricing attempts to i) identify how much of a property differential is due to a particular environmental difference between properties and ii) infer how much people are	Cultural services.	It can isolate the effects of ES on land value, under the assumption that those services are fully reflected in land prices.	It relies on a large amount of high-quality data on property price.

	willing to pay for an improvement in the environmental quality that they face and what the social value of improvement is.”			
Contingent valuation **(Bateman and Turner, 1993)**	“Environmental evaluations are obtained by using surveys to ask people directly what they are willingness to pay or willingness to accept for a given gain or loss of a specified good.”	Any services.	It allows for a high degree of flexibility in the formulation of the questions, including the valuation of scenarios that are yet to happen.	Respondents’ valuation can be influenced by their prior knowledge, and by what they are told in the questionnaire. Hence, bias issues in survey design should be taken into account. It is based on hypothetical behavior.
Choice modelling **(Christie et al., 2008)**	“The choice modelling technique estimates economic values by constructing a hypothetical market for the non-market environmental good.”	Any services.	Respondents do not have to give a price valuation of the natural resource, but just need to select their preferred policy option, thus ruling out any sort of bias related to respondents’ lack of knowledge about monetary economy.	It is more complex to analyze and to explain to the respondents, who may not look at the policy characteristics as a bundle but focus only on one attribute.

Table 4: Assessment of methodologies for ES valuation at the urban level

CASE STUDIES on economic valuation.

A literature review of case studies carrying out economic valuation of ES has been performed. They can be used as reference for future studies.

The **ex-post valuation** is more complex given the different methodology to adopt based on the NBS to value. Table 6 shows economic valuation studies whose analyses have been carried out by using the valuation methodologies introduced in the previous step “Methodology”. The case studies can be used and analyzed to better identify the methodology to be used and to replicate it.

Method.	NBS	ES	Input/data	Comments	Bibliography
Market prices	Urban forest	Carbon sequestration	Photosynthesis capability (carbon sequestration and oxygen release rates); carbon tax and industrial production cost of oxygen were used as marginal cost	/	Leng, P. et al. (2004). Economic valuation of urban greenspace ecological benefits in Beijin city. *Journal of Beijing Agricultural College 19(4)*, 25-28 (in Chinese).
	Urban forest	Air purification	Particulate removal rates; area of urban forest; marginal cost of one unit of particulate	Use of total urban forest area instead of total land use area as in western studies	Zhang, W. et al. (2006). Initial analysis on the ecological service value of the greening land in Lanzhou city. *Pratacultural Science 23(11)*, 98-102 (in Chinese).
Replacement cost	Eurasian Jays	Seed dispersal	Forest area, Number of oaks due to seed dispersal, number of saplings per year due to jays; cost of manual seeding; cost of planting oak saplings. Man-made seed/sapling planting is used as replacement cost	/	Hougner, C., Colding, J., and Söderqvist, T. (2006). Economic valuation of a seed dispersal service in the Stockholm National Urban Park, Sweden. *Ecological economics*, *59*(3), 364-374.

	Urban forest	Temperature regulation	Residential cooling and heating energy use; commercial electric rates; residential density; size of commercial structures; changes in solar radiation, air temperature and wind speed by trees; tree cover area; tree density; land use; retail costs of energy to residential and commercial customers are used as replacement costs	Results are presented for the entire county, as well as by sector, vintage, and building type; impacts on high- versus low-density residential building types, residential versus commercial buildings, and old versus new vintages are presented as well.	Simpson, J. R. (1998). Urban forest impacts on regional cooling and heating energy use: Sacramento county case study. *Journal of Arboriculture 24(4)*, 201-214.
	Urban forest	Temperature regulation	Data on evotranspiration effect and latent heat consumption of trees; replacement cost of the amount of electrical power consumption required to achieve the same cooling effect in 100 summer day per annum	/	Leng, P. et al. (2004). Economic valuation of urban greenspace ecological benefits in Beijin city. *Journal of Beijing Agricultural College 19(4)*, 25-28 (in Chinese).

Damage cost avoided	Urban forest	Air purification	Sulphure dioxide removal rates; area of urban forest; fees levied on pollutant emissions from industrial sources is used as replacement cost	Use of total urban forest area instead of total land use area as in western studies	Zhang, W. et al. (2006). Initial analysis on the ecological service value of the greening land in Lanzhou city. *Prataculture Science 23(11)*, 98-102 (in Chinese).
	Fluvial floodable parks; green roofs	Flood prevention	Construction unit basic cost; % of building structure damaged by flooding; built flooded area; standard cost of typical building content; % of contents damaged; Number of flooded houses	The presence of green roof provides further resilience but leads to a significant rise in costs as well	Miguez, M. G., Raupp, I. P., and Veról, A. P. (2018). An integrated quantitative framework to support design of resilient alternatives to manage urban flood risks. *Journal of Flood Risk Management*, e12514.
	Urban forest	Air purification	N.A.	/	Capotorti, G. et al. (2017). Biodiversity and ecosystem services in urban green infrastructure planning: A case study from the metropolitan area of Rome (Italy). *Urban Forestry & Urban Greening*.

	Urban forest	Air purification	N.A.	/	Chaparro, L., and Terradas, J. (2009). Ecological services of urban forest in Barcelona. *Institut Municipal de Parcs i Jardins Ajuntament de Barcelona, Àrea de Medi Ambient*.
	Urban forest	Air purification	N.A.	/	McPherson, E. G., Nowak, D. J., and Rowntree, R. A. (1994). Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. *Gen. Tech. Rep. NE-186. Radnor, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 20*, 186.
	Urban forest	Air purification	N.A.	/	Scott, K. I., McPherson, E. G., and Simpson, J. R. (1998). Air pollutant uptake by Sacramento's urban forest. *Journal of Arboriculture*, *24*, 224-234.

	Urban forest	Air purification	N.A.	/	Nowak, D. J. et al. (2007). Assessing urban forest effects and values: Philadelphia's urban forest. *Resource Bulletin-Northern Research Station, USDA Forest Service*, (NRS-7).
	Urban forest	Temperature regulation	N.A.	/	McPherson, E. G. et al. (1997). Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban ecosystems*, *1*(1), 49-61.
	Urban green (street and park trees)	Temperature regulation	N.A.	/	McPherson, E. G., Simpson, J. R., Peper, P. J., and Xiao, Q. (1999). Benefit-cost analysis of Modesto's municipal urban forest. *Journal of Arboriculture*, *25*, 235-248.
	Urban green (street and park trees)	Carbon sequestration	N.A.	/	
	Municipal trees	Carbon sequestration	N.A.	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for*
	Municipal trees	Air purification	N.A.	/	
	Municipal trees	Water run-off	N.A.	/	

		reduction			*Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis*.
	Municipal trees	Temperature regulation	N.A.	/	
	Urban forest	Carbon sequestration	N.A.	/	Nowak, D. J. et al. (2007). Assessing urban forest effects and values: Philadelphia's urban forest. *Resource Bulletin-Northern Research Station, USDA Forest Service*, (NRS-7).
Travel cost	Urban green spaces	Outdoor worship	Structured interview to understand visit purpose and individual characteristics; Questionnaire to get info about worship in green areas (reason why, challenges, intervention required; frequency, means and costs of travelling)	/	Ngulani, T., and Shackleton, C. M. (2019). Use of public urban green spaces for spiritual services in Bulawayo, Zimbabwe. *Urban Forestry & Urban Greening*, *38*, 97-104.
	Urban Wetland Parks	Recreational value	Time for tourist to travel; monthly salary of tourists; travel expenses (tickets, accommodation, fares, group fees and shopping); travel	/	Wang, Y. et al. (2019). Framework for valuating urban wetland park ecosystem services based on the cascade approach. *Polish*

			consumption intention. All data are obtained from a questionnaire		*Journal of Environmental Studies, 28(4)*, 2429-2440. DOI: 10.15244/pjoes/91938
Hedonic pricing	Municipal trees	Amenity value	N.A.	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis*.
	Urban green spaces	Amenity value	Price, date, and type of sale; Structural characteristics of the property; property location; Size, distance from house and from apartment of greenurban spaces	Urban green space is divided into 8 categories according to accessibility, maintainance level, and neighbouring negative land use: parks, lakes, nature, churchyards, sportfields, common areas, green buffer, agriculture fields	Panduro, T.E., Veie, K.L. (2013). Classification and valuation of urban green spaces—A hedonic house price valuation. *Landscape and Urban Planning 120,* 119-128.

	Urban forest	Amenity value	House price per square meter as a function of: environmental quality characteristics such as distance to the nearest wooded recreation area, to the nearest forested area, and the relative amount of forested areas in the housing district; apartmente characteristics such as size, age, and type of construction; local attributes such as accessibility to town center, school and shops	Unexpectedly distance to forested parks has a negative impact on house prices but this could be explained both by the fact that 80% of the houses were less than a 100m close to such parks and that residents would be better off without the additional shading provided by those trees given the limited amount of sunlight the area receives.	Tyrväinen, L. (1997). The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban planning*, *37*(3-4), 211-222.
	Street trees	Amenity value	House price was regressed on house and market neighbourhood amenities including street tree variables (20 variables in total)	/	Donovan, G. H., & Butry, D. T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and urban planning*, *94*(2), 77-83.

Contingent valuation	Urban forest	Recreational value	Transaction data of residential properties in the housing market.	/	Jim, C. Y. and Chen, W. Y. (2007). Consumption preferences and environmental externalities: A hedonic analysis of the housing market in Guangzhou (China). *Geoforum 38*, 414–431
	Urban forest	Amenity value	Questionnaire survey, questions include: willingness to pay for main recreation areas; willingness to pay to prevent the development of urban forest parks for housing purpose; attitueds towards the use of urban forests; socio-economic characteristics of respondents	/	Tyrväinen, L. and Väänänen, H. (1998). The economic value of urban forest amenities: an application of the contingent valuation method. *Landscape and Urban Planning 43*, 105–118.
	Urban forest	Recreational value	Questionnaire survey	Income level was found to have a positive impact on their willingness to pay	Jim, C. Y., and Chen, W. Y. (2006). Recreation–amenity use and contingent valuation of urban greenspaces in Guangzhou, China. *Landscape and*

					urban planning, *75*(1-2), 81-96.
Choice modelling	Green building development	Water provisioning; Temperature regulation; Air quality	Questionnaire surveys, questions include: awareness and understanding level on green development; pairs of choice cards to reveal willingness to pay for different aspects of environmental performance for a green development; participants socio-economic details (age, education and income level)	Ecosystem services of recreational and amenity value, and noise reduction were considered but not assessed	Chau, C.K., Tse, M.S., and Chung, K.Y. (2010). A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes. *Building and Environment, 45(11),* 2553-2561.
	Urban forest	Temperature regulation	Forest area per capita; per capita road size; per capita number of cars; socio-economic characteristics	/	Kim, D-H., Ahn, B-I., and Kim, E-G. (2016). Metropolitan Residents' Preferences and Willingness to Pay for a Life Zone Forest for Mitigating Heat Island Effects during Summer Season in Korea.

Table 6: NBS valuation at the urban level: case studies repository

3. Definition of the monitoring strategy

The monitoring strategy is fundamental to allow the measurement of the impacts generated by NBS and to assess the ES provided by them. Through the definition of a monitoring strategy, it will be possible to define a baseline and to compare it after the implementation of the NBS.

Table 7 shows a set of KPIs which can be used in the monitoring strategy. These KPIs have been obtained from several frameworks such as the Agenda 2030, Eklipse, Maes and TEEB. Further details on KPIs can be found in the deliverable D5.1 of URBAN GreenUP project.

ECOSYSTEM SERVICES	CLASS	KPI	SCALE R=Regional M=Metropolitan U=Urban S=Street B=Building
Cultural	Physical use of land/seascapes in different environmental settings	Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014).	R M U S
		Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al. 2015)	U
		Accessibility (Schipperijn et al., 2010): distribution, configuration, and diversity of green space and land use changes (multi-scale; Goddard et al., 2010).	R M U
		Increase in walking and cycling in and around areas of interventions	M U S
	Social engagement	Perceptions of citizens on urban nature (Buchel and Frantzeskaki, 2015; Colding and Barthel, 2013; Gerstenberg and	R M U
		Green intelligence awareness	M U
		Number of jobs created (Forestry Commission, 2005); gross value added (Forestry Commission, 2005).	R M U
Provisioning	Surface/groud water for drinking	Drinking water provision (m3 ha-1year-1)	M U
	Surface/groud water for non-drinking	Water for irrigations purposes (m3 ha-1year-1)	R M
	Cultivated crops	Production of food (ton ha-1 year-1)	M U
Regulation	Filtration/sequestration/storage/accumulation by ecosystems	Tonnes of carbon removed or stored per unit area per unit time (Zheng et al., 2013), total amount of carbon (tonnes)	>R
		Run-off coefficient in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et	R M U S B
	Micro and regional climate regulation	Temperature reduction in urban areas (°C, % of energy reduction for cooling) (Demuzere et al., 2014).	R M U S
		Decrease in mean or peak daytime local temperatures (oC) (Demuzere et al., 2014).	R M U
		Heatwave risks (number of combined tropical nights (>20oC) and hot days (>35oC)) following Fischer, Schär, 2010,	R M U
		Use of Star tools to calculate projected maximum surface temperature reduction	M U
	Hydrological cycle	Volume of water removed from water treatment system	U S B
		Volume of water slowed down entering sewer system	U S B
	Flood protection	Areas (ha) and population exposed to flooding	M U
		Shoreline characteristics and erosion protection	R M
		Flooding characteristics	U
	Global climate regulation by reduction of GHG concentration	11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)	M U
		Trends in emissions NOX, SOX	M U
		Air quality parameters Nox, VOC, PM etc	M U
		Monetary values: value of air pollution reduction (Manes et al., 2016); total monetary value of urban forests including	M U
		Savings in energy use due to improved GI	M U
	Mediation of smell/noise/visual	Noise reduction rates applied to UGI within a defined road buffer dB(A) m-2 vegetation unit (Derkzen et al. 2015)	U S
Supporting	Habitat for species	Absorption capacity of green surfaces, bioretention structures and single trees (Armson et al., 2013; Davis et al., 2009)	S B
		Estimates of species, individuals and habitats distribution	R M
		Increased connectivity to existing GI	M U S
		Pollinator species increase	U S
		Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9)	M U

Table 7: Set of core KPIs

4. Identification of the stakeholders to involve

The identification of the stakeholders that need to be involved in the different activities of the project is fundamental in particular in the monitoring process. Table 8 shows a list of stakeholders that the municipality can choose from and that can be involved in the monitoring and valuation of NBS benefits. When it comes to implementing NBS, stakeholders can contribute to different phases: the design, the construction, the monitoring and the management. More than one stakeholder can be involved in the design, construction and management phases. Therefore, local authorities need to evaluate which stakeholder could be interested in the project and what role it could fulfil.

Stakeholders
City government
City agencies
Utilities
Non-governmental associations
Urban designers and planners
Developers
Real estate
Financing and insurance institutions
Citizens
Research (Universities, research centers)

Table 8: List of stakeholders to involve in the project

5. Tools for the valuation of ES

Several tools have been designed to perform an ex-post valuation of the ES provided by NBS at the urban level. These are made to assist decision-makers in the integration of ecosystems and their services into policy and planning decisions. In order to choose the appropriate tool, it is necessary to understand: i) which ES can be measured with that tool; ii) the availability of data at their disposal, and; iii) at which scale it is possible to carry out the evaluation.

Table 9 shows the main tools that have been used in the literature to gauge ES in monetary terms. It also illustrates the main ES that each tool can value.

Tool	Ecosystem Services valued
BeST (Benefits of SuDS Tool)	Cultural (health, education, amenity); regulating (climate, carbon, flooding); and supporting (biodiversity)
CITYgreen	Air pollution removal; Water quality (runoff)
Co$ting Nature	Water provisioning and supply; water quality; carbon sequestration; carbon storage; flood regulation; nature-based tourism (including recreational and aesthetic value)
GI-Val (Green Infrastructure Valuation Toolkit)	Climate change adaptation & mitigation; Water management & flood alleviation; Health & well-being; Labor productivity; Tourism; Recreation & leisure; Biodiversity; Land management
HEAT (Health Economic Assessment Tools)	Health benefits
i-Tree (previously UFORE)	Carbon sequestration
ORVal	Recreational value
The National Green Value Calculator	Run off reduction

Table 9: List of tools that carry out economic valuation of ES in monetary terms.

Annex A1. Methodologies for ecosystem services valuation at urban level – case studies

Method.	Loc.	Year	ES provider	ES	Input/data	Economic valuation	Benef.	Comments	Bibliography
Market prices	Beijing China	N.A.	Urban forest	Carbon sequestration	Photosynthesis capability (carbon sequestration and oxygen release rates); carbon tax and industrial production cost of oxygen were used as marginal cost	RMB 1.18 x 10^9/year (oxygen release); RMB 2.62 x 109/year (carbon sequestration)	Citizens	/	Leng, P. et al. (2004). Economic valuation of urban greenspace ecological benefits in Beijin city. *Journal of Beijing Agricultural College 19(4)*, 25-28 (in Chinese).
	Lanzhou China	N.A.	Urban forest	Air purification	Particulate removal rates; area of urban forest; marginal cost of one unit of particulate	RMB 0.91 x 10^6/year	Citizens	Use of total urban forest area instead of total land use area as in western studies	Zhang, W. et al. (2006). Initial analysis on the ecological service value of the greening land in Lanzhou city. *Pratacultural Science 23(11*), 98-102 (in Chinese).
Replacement cost	Stockholm national urban park Sweden	N.A.	Eurasian Jays	Seed dispersal	Forest area, Number of oaks due to seed dispersal, number of saplings per year due to jays; cost of manual seeding; cost of planting oak saplings. Man-made seed/sapling planting is used as replacement cost	SEK 35000 - 160000 /ha	Citizens	/	Hougner, C., Colding, J., and Söderqvist, T. (2006). Economic valuation of a seed dispersal service in the Stockholm National Urban Park, Sweden. *Ecological economics*, *59*(3), 364-374.

	Sacramento USA	N.A.	Urban forest	Temperature regulation (through shade, air temperature and wind speed effects)	Residential cooling and heating energy use; commercial electric rates; residential density; size of commercial structures; changes in solar radiation, air temperature and wind speed by trees; tree cover area; tree density; land use; retail costs of energy to residential and commercial customers are used as replacement costs	US$19.8 million	Energy residential customers; energy commercial customers	Results are presented for the entire county, as well as by sector, vintage, and building type; impacts on high- versus low-density residential building types, residential versus commercial buildings, and old versus new vintages are presented as well.	Simpson, J. R. (1998). Urban forest impacts on regional cooling and heating energy use: Sacramento county case study. *Journal of Arboriculture 24(4)*, 201-214.
	Beijing China	N.A.	Urban forest	Temperature regulation (through evotranspiration)	Data on evotranspiration effect and latent heat consumption of trees; replacement cost of the amount of electrical power consumption required to achieve the same cooling effect in 100 summer day per annum	RMB 93.5 x 10^6/year	Energy residential customers; energy commercial customers	/	Leng, P. et al. (2004). Economic valuation of urban greenspace ecological benefits in Beijin city. *Journal of Beijing Agricultural College 19(4)*, 25-28 (in Chinese).

	Lanzhou China	N.A.	Urban forest	Air purification	Sulphure dioxide removal rates; area of urban forest; fees levied on pollutant emissions from industrial sources is used as replacement cost	RMB 0.28 x 10^6/year	Citizens	Use of total urban forest area instead of total land use area as in western studies	Zhang, W. et al. (2006). Initial analysis on the ecological service value of the greening land in Lanzhou city. *Pratacultural Science 23(11)*, 98-102 (in Chinese).
Damage cost avoided	Rio de Janeiro Brasil	N.A.	Fluvial floodable parks; green roofs	Flood prevention	Construction unit basic cost; % of building structure damaged by flooding; built flooded area; standard cost of typical building content; % of contents damaged; Number of flooded houses	US$ 19740390.37 (including green roofs); US$ 16320813.73 (without green roofs) over a 50 year period	Residents	The presence of green roof provides further resilience but leads to a significant rise in costs as well	Miguez, M. G., Raupp, I. P., and Veról, A. P. (2018). An integrated quantitative framework to support design of resilient alternatives to manage urban flood risks. *Journal of Flood Risk Management*, e12514.
	Rome Italy	2005	Urban forest	Air purification	N.A.	€ 40700-130200/year	Citizens	/	Capotorti, G. et al. (2017). Biodiversity and ecosystem services in urban green infrastructure planning: A case study from the metropolitan area of Rome (Italy). *Urban Forestry & Urban Greening*.
	Bracelona Spain	2008	Urban forest	Air purification	N.A.	€ 1.115.908	Citizens	/	Chaparro, L., and Terradas, J. (2009). Ecological services of urban forest in Barcelona. *Institut Municipal de Parcs i Jardins Ajuntament de Barcelona, Àrea de Medi Ambient*.

	Chicago USA	1991	Urban forest	Air purification	N.A.	US$9.2 million	Citizens	/	McPherson, E. G., Nowak, D. J., and Rowntree, R. A. (1994). Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. *Gen. Tech. Rep. NE-186. Radnor, PA: US Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 20*, 186.
	Sacramento USA	1990	Urban forest	Air purification	N.A.	US$28.7 million (US$1500/ha)	Citizens	/	Scott, K. I., McPherson, E. G., and Simpson, J. R. (1998). Air pollutant uptake by Sacramento's urban forest. *Journal of Arboriculture*, *24*, 224-234.
	Philadelphia USA	N.A.	Urban forest	Air purification	N.A.	US$3.9 million/year	Citizens	/	Nowak, D. J. et al. (2007). Assessing urban forest effects and values: Philadelphia's urban forest. *Resource Bulletin-Northern Research Station, USDA Forest Service*, (NRS-7).
	Chicago USA	1991	Urban forest	Temperature regulation	N.A.	US$15 (cooling) and US$10 (heating)	Energy residential customers; energy commercial customers	/	McPherson, E. G. et al. (1997). Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban ecosystems*, *1*(1), 49-61.

	Modesto USA	1998	Urban green (street and park trees)	Temperature regulation	N.A.	US$870000 (US$10/tree)	Energy residential customers; energy commercial customers	/	McPherson, E. G., Simpson, J. R., Peper, P. J., and Xiao, Q. (1999). Benefit-cost analysis of Modesto's municipal urban forest. *Journal of Arboriculture*, *25*, 235-248.
	Modesto USA	1998	Urban green (street and park trees)	Carbon sequestration	N.A.	US$460000 (US$5/tree)	Citizens	/	McPherson, E. G., Simpson, J. R., Peper, P. J., and Xiao, Q. (1999). Benefit-cost analysis of Modesto's municipal urban forest. *Journal of Arboriculture*, *25*, 235-248.
	New York USA	2005	Municipal trees	Carbon sequestration	N.A.	US$754947 (US$1.29/tree)	Citizens	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis*.
	New York USA	2005	Municipal trees	Air purification	N.A.	US$5.3 million (US$9.02/tree)	Citizens	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis*.
	New York USA	2005	Municipal trees	Water run-off reduction	N.A.	US$35.6 million (US$61/tree)	Citizens	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest*

									Service, Pacific Southwest Research Station, Davis.
	New York USA	2005	Municipal trees	Temperature regulation	N.A.	US$27.8 million (US$47.63/tree)	Citizens	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis.*
	Philadelphia USA	N.A.	Urban forest	Carbon sequestration	N.A.	US$9.8 million (carbon storage) and US$297000 (carbon sequestration)	Citizens	/	Nowak, D. J. et al. (2007). Assessing urban forest effects and values: Philadelphia's urban forest. *Resource Bulletin-Northern Research Station, USDA Forest Service*, (NRS-7).
Travel cost	Bulawayo Zimbabwe	2015	Urban green spaces	Outdoor worship	Structured interview to understand visit purpose and individual characteristics; Questionnaire to get info about worship in green areas (reason why, challenges, intervention required; frequency, means and costs of travelling)	US$ 29-244/ha/year	Residents	/	Ngulani, T., and Shackleton, C. M. (2019). Use of public urban green spaces for spiritual services in Bulawayo, Zimbabwe. *Urban Forestry & Urban Greening*, *38*, 97-104.
	Guiyang China	2015	Urban Wetland Parks	Recreational value	Time for tourist to travel; monthly salary of tourists; travel expenses (tickets, accommodation, fares, group fees and shopping); travel	RMB 1.38 x 10^9	Park visitors	/	Wang, Y. et al. (2019). Framework for valuating urban wetland park ecosystem services based on the cascade approach. *Polish Journal of Environmental Studies, 28(4)*, 2429-2440.

					consumption intention. All data are obtained from a questionnaire				DOI: 10.15244/pjoes/91938
Hedonic pricing	New York USA	2005	Municipal trees	Amenity value	N.A.	US$52.5 million (US$90/tree)	Resident s	/	Peper, P. J.et al. (2007). New York City, New York municipal forest resource analysis. *Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Davis*.
	Aalborg Denmar k	Data on houses: from 2000 to 2007; data on green areas: in 2003, 2008, and 2010	Urban green spaces	Amenity value	Price, date, and type of sale; Structural characteristics of the property; property location; Size, distance from house and from apartment of green urban spaces	1% increase in park area increases surrounding house prices by 0.01%; View on a park increase price of apartment by 6%; view on a lake increases house price by 7%; Reduced distance from park increases house price by up to 2.7% and apartment price by 2.1% (considering a 100 m distance)	Resident s	Urban green space is divided into 8 categories according to accessibility, maintainance level, and neighbouring negative land use: parks, lakes, nature, churchyards, sportfields, common areas, green buffer, agriculture fields	Panduro, T.E., Veie, K.L. (2013). Classification and valuation of urban green spaces—A hedonic house price valuation. *Landscape and Urban Planning 120,* 119-128.

	Joensuu Finland	1984-1986	Urban forest	Amenity value	House price per square meter as a function of: environmental quality characteristics such as distance to the nearest wooded recreation area, to the nearest forested area, and the relative amount of forested areas in the housing district; apartmente characteristics such as size, age, and type of construction; local attributes such as accessibility to town center, school and shops	A 100m decrease in the distance to: a recreation area increases house price by 42 FIM; a watercourse increases house price by 154 FIM. 1% increase in green space (= lower housing density) increases house price by 7 FIM	Residents	Unexpectedly distance to forested parks has a negative impact on house prices but this could be explained both by the fact that 80% of the houses were less than a 100m close to such parks and that residents would be better off without the additional shading provided by those trees given the limited amount of sunlight the area receives.	Tyrväinen, L. (1997). The amenity value of the urban forest: an application of the hedonic pricing method. *Landscape and Urban planning*, *37*(3-4), 211-222.
	Portland USA	2007	Street trees	Amenity value	House price was regressed on house and market neighbourhood amenities including street tree variables (20 variables in total)	The number of trees and crown area combined and computed at their mean add US$ 8870 to	Residents	/	Donovan, G. H., & Butry, D. T. (2010). Trees in the city: Valuing street trees in Portland, Oregon. *Landscape and urban planning*, *94*(2), 77-83.

						the house price (equivalent to 3% of median sales price)			
	Guangz hou China	2004	Urban forest	Recreational value	Transaction data of residential properties in the housing market.	6.6% reduction in house price with doubling the distance from park; park view increases house price by 8.6%	Resident s	/	Jim, C. Y. and Chen, W. Y. (2007). Consumption preferences and environmental externalities: A hedonic analysis of the housing market in Guangzhou (China). *Geoforum 38*, 414–431
Contingent valuation	Joensuu Finland	1995	Urban forest	Amenity value	Questionnaire survey, questions include: willingness to pay for main recreation areas; willingness to pay to prevent the development of urban forest parks for housing purpose; attitueds towards the use of urban forests (pros and cons of urban parks; use of different areas and type of recreation); socio-economic characteristics of respondents	US$0.8 million	Citizens	/	Tyrväinen, L. and Väänänen, H. (1998). The economic value of urban forest amenities: an application of the contingent valuation method. *Landscape and Urban Planning 43*, 105–118.
	Guangz hou China	2003	Urban forest	Recreational value	Questionnaire survey	RMB 547.09 x 10^6/year	Citizens	Income level was found to have a positive	Jim, C. Y., and Chen, W. Y. (2006). Recreation–amenity use and contingent valuation of urban greenspaces in

								impact on their willingness to pay	Guangzhou, China. *Landscape and urban planning*, *75*(1-2), 81-96.
Choice modelling	Yuen Long and Eastern district Hong Kong	N.A.	Green building developme nt	Water provisioning; Temperature regulation; Air quality	Questionnaire surveys, questions include: awareness and understanding level on green development; pairs of choice cards to reveal willingness to pay for different aspects of environmental performance for a green development; participants socio-economic details (age, education and income level)	WTP of high-income residents for a 20% reduction in monthly consumption level: HK$11.1 for water consumption; HK$35.1 for energy consumption; HK$18.5 for improved air quality. WTP of low-income residents for a 20% reduction in monthly consumption level: HK$10.1 for water consumption; HK$32 for energy consumption; HK$16.8 for improved air quality.	Resident s	Ecosystem services of recreational and amenity value, and noise reduction were considered but not assessed	Chau, C.K., Tse, M.S., and Chung, K.Y. (2010). A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green building attributes. *Building and Environment, 45(11),* 2553-2561.

	N.A. South Corea	2010	Urban forest	Temperature regulation	Forest area per capita; per capita road size; per capita number of cars; socio-economic characteristics (gender, residential region, housing type, age, monthly household income, marriage, number of family members, occupation, residential city)	from US$56.68 to US$76.59 per m^2 of additional urban forest	Citizens	/	Kim, D-H., Ahn, B-I., and Kim, E-G. (2016). Metropolitan Residents' Preferences and Willingness to Pay for a Life Zone Forest for Mitigating Heat Island Effects during Summer Season in Korea. *Sustainability, 8(11),* 1155.
Deliberative monetary valuation					N.A.			/	
Questionnaires	Barcelona Spain	2015	Urban gardens	2 provisioning, 5 regulating, 12 cultural and 1 supporting	N.A.	Cultural services were valued the highest, with an average of 4.49 out of 5	Citizens	Semi structured interviews were held to identify ecosystem services provided by urban gardens	Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., and Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. *Environmental Science & Policy*, *62*, 14-23.

	Guangzhou China	2003	Urban parks	25 ecosystem services divided into 6 groups (microclimate, environmental quality, environmental function, recreation and landscape, economic benefits, other functions)	N.A.	Ecosystem services contributing to the amelioration of urban microclimate and environmental quality were ranked the highest	Park visitors	/	Jim, C. Y., and Chen, W. Y. (2006). Perception and attitude of residents toward urban green spaces in Guangzhou (China). *Environmental management*, *38*(3), 338-349.
	Tzaneen and Bela-Bela South Africa	2011	Urban green areas	1 provisioning, 2 regulating, and 4 cultural)	Questionnaire to obtain data on the direct uses of trees (provisioning services); recognition and appreciation of intangible benefits of trees and the urban forest (regulating and cultural services)	In more established neighborhoods trees assume more aesthetic, cultural and environmental importance, while their role in regulating temperature tends to be widely appreciated regardless of living conditions	Citizens	Results differed depending on where the respondents were living (RDP areas, informal settlements, or townships)	Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., and Kaoma, H. (2015). Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. *Landscape and Urban Planning*, *136*, 76-86.

In-depth interviews	Tzaneen and Bela-Bela South Africa	2011	Urban green areas	1 provisioning, 2 regulating, and 4 cultural	N.A.	In more established neighborhoods trees assume more aesthetic, cultural and environmental importance, while their role in regulating temperature tends to be widely appreciated regardless of living conditions	Citizens	Results differed depending on where the respondents were living (RDP areas, informal settlements, or townships)	Shackleton, S., Chinyimba, A., Hebinck, P., Shackleton, C., and Kaoma, H. (2015). Multiple benefits and values of trees in urban landscapes in two towns in northern South Africa. *Landscape and Urban Planning*, *136*, 76-86.
	Barcelona Spain	2015	Urban gardens	2 provisioning, 5 regulating, 12 cultural and 1 supporting	N.A.	Cultural services were valued the highest, with an average of 4.49 out of 5	Citizens	Questionnaires were handed out to obtain info on valuation of the ecosystem services	Camps-Calvet, M., Langemeyer, J., Calvet-Mir, L., and Gómez-Baggethun, E. (2016). Ecosystem services provided by urban gardens in Barcelona, Spain: Insights for policy and planning. *Environmental Science & Policy*, *62*, 14-23.
Q methodology	Rotterdam The Netherlands	2013	Urban parks	Cultural services (7), Regulating services (3)	N.A.	Aesthetic appreciation is the most valued ecosystem service across the board; recreation, air quality control and social	Park visitors	/	Buchel, S., and Frantzeskaki, N. (2015). Citizens' voice: A case study about perceived ecosystem services by urban park users in Rotterdam, the Netherlands. *Ecosystem Services*, *12*, 169-177.

						setting scored highly in two out of three factors; sense of place scored the highest in one of the three profiles.			

Annex A2. Tools for ecosystem services valuation

Name	Functions	Approach	Scale	Link
GI-Val (Green Infrastructure Valuation Toolkit)	The Green Infrastructure Valuation toolkit provides a set of calculator tools to assess the value of a green asset or a proposed green investment. Where possible, the benefits of green infrastructure (GI) are given an economic value. Other quantitative (e.g. number of jobs) and qualitative (e.g. links to case studies or research) contributions can also be provided to give a complete view of the value of an asset. The benefits provided by GI are assessed in terms of the function that it may perform, support or encourage. Benefits are grouped into 20 ecosystem services. The tool provides insight into key evidence and concepts from a range of sectors including economic development and regeneration, public health and nature conservation.	The input data required are about the project area and local population statistics in an Excel spreadsheet. Input data can come from a wide variety of sources, including government statistics, site surveys and masterplans, the internet, and geographic data processed using a geographic information system (which may include green infrastructure mapping). If ideal source data is not available, input values can usually be estimated using proxies, or alternatively the tools relying on the data can be easily excluded.	Site scale, Local scale	https://www.merseyforest.org.uk/services/gi-val/
BeST (Benefits of SuDS Tool)	Estimates are based on the performance of the whole drainage system rather than individual components. BeST uses the ecosystem services approach to understand the overall benefits that SuDS provide over conventional piped drainage. Using values input by the user, it provides support to quantify and monetise the benefits of a SuDS scheme for a given area over a specified time period.	The input data required are SuDS scheme data in an Excel spreadsheet: Site data (e.g. location, area, baseline option), SuDS components (e.g. number, type and size of trees; area of green roofs, swales, basins and wetlands), Habitat type (e.g. BAP habitat), Number/type of homes and number of people affected by a change in flood risk, amenity value or health, Non-expert qualitative assessment of potential impacts on crime, economic growth, education, tourism and traffic-calming, Avoided drainage / sewerage infrastructure costs, Volume of water infiltrating for groundwater recharge, Change in energy use due to reduced wastewater pumping, Number of properties adopting rainwater harvesting, and household water consumption rates, Change in level and type of recreation due to scheme, Change in wastewater flow and runoff, Current and projected water quality status. Where possible it estimates the economic value of the changes.	Site scale, Local scale	https://www.susdrain.org/resources/best.html
i-Tree	i-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry	Tree measurements and field data are entered into the Eco application either by web form or by manual data entry, they are	Site scale, Local scale,	http://www.itreetools.org/

	analysis and benefits assessment tools. The i-Tree tools can help strengthen forest management and advocacy efforts by quantifying forest structure and the environmental benefits that trees provide	merged with local pre-processed hourly weather and air pollution concentration data. These data make it possible for the model to calculate structural and functional information using a series of scientific equations or algorithms.	Regional scale, Multi-scale	
ARIES (ARtificial Intelligence for Ecosystem Services)	It is a networked collaborative software technology designed for rapid ecosystem service assessment and valuation. It gives equal emphasis to ecosystem service supply, demand and flow in order to quantify actual service provision and use by society (as opposed to quantifying potential service benefits). It aims to provide a suite of models that support science-based decision-making.	The input data required are spreadsheets, databases (e.g. Access), maps (global maps are available by default online) or GIS databases. ARIES uses artificial intelligence to pair ES models with spatial data in order to quantify ES flows for a study area. The software will prioritize specific process-based models and revert to simpler models where required. It is based on k.LAB technology which allows researchers to contribute models and scientific data that simulate and integrate environmental and socioeconomic systems.	Local scale, Landscape scale, Regional scale, National scale, Multi-scale	http://aries.integratedmodelling.org/
Co$ting Nature	It is a web based policy-support tool for natural capital accounting and analysis of the ecosystem services provided by natural environments. The tool estimates the current provision of water, carbon and tourism services and identifies the beneficiaries, then analyses current environmental pressures, future threats and conservation priority. Users can then apply scenarios for climate, land-use or land management change, and examine the impacts on ecosystem services and the implications for beneficiaries. The tool can be used to assess the impacts of human interventions for conservation prioritisation and planning.	The input data required are Global spatial data (GIS, remote sensing) at 1 square km or 1 ha resolution (provided by the tool). Users can also provide their own datasets. It calculates a baseline for current ecosystem service provision (1950-2000). It also allows interventions (policy options) or scenarios of change to be used to understand their impact on ecosystem service delivery. By combining more than 80 input maps, the tool calculates the spatial distribution of ecosystem services for water, carbon and tourism and combines these with maps of conservation priority, threatened biodiversity and endemism to understand the spatial distribution of critical ecosystems. These data are combined with human pressures and future threats to determine conservation priorities. Outputs are a series of summary maps expressed in relative terms (0 - 1) which combine the outputs from the different modules (ecosystem service bundles).	Local scale, Landscape scale, Regional scale, National scale, Multi-scale	http://www.policysupport.org/costingnature
EcoServ-GIS	EcoServ-GIS is a Geographic Information System (GIS) toolkit for mapping ecosystem services at a county or regional scale. It uses input GIS/map data to generate fine-scale maps that illustrate human need or demand for ecosystem services as well as the capacity of the natural environment to provide them.	The datasets required to work on EcoServ-GIS are: OS MasterMap, Study Area boundary and OS VectorMap. The remaining data are all optional, but in several cases will greatly add to the usefulness of the toolkit inputs. EcoServ-GIS overlays spatial datasets incorporating aspects of the physical landscape (e.g. habitat) and socio-economic factors (e.g. health deprivation). Capacity and	Local scale, Landscape scale, Regional scale	/

		Demand map outputs can be overlaid to visualise areas where they coincide ("benefiting areas"), or where action is needed to improve service delivery ("management zones"). The outputs can also be used to create Ecological Habitat Network maps (to show where areas are more or less connected to a wider network of sites for focal species) and Biodiversity Opportunity Area Maps (to identify areas where habitat creation or habitat buffering might be suitable).		
InVEST (Integrated Valuation of Ecosystem Services and Trade-offs)	It is a suite of open-source software models for mapping and valuing the ecosystem services provided by land and seascapes. It is designed to inform decisions about natural resource management.	It uses predominantly GIS / map data and information tables (usually.csv format. The input dataset required depends by model used (Carbon Storage and Sequestration, Coastal Blue Carbon, Crop Pollination, etc.). It consists of 18 software models for mapping and valuing ecosystem services, plus a number of supporting tools to help with preparing, processing and visualising data. Models can be applied at multiple scales. Most models use a 'production function' approach, meaning that the ecosystem service output (map) is derived using information about environmental condition and processes. The final map result is expressed in either biophysical terms (i.e. a quantity) or economic terms.	Site scale, Local scale, Landscape scale, Regional scale, National scale, Multi-scale	http://naturalcapitalproject.stanford.edu/invest/
NCPT (The Natural Capital Planning Tool)	The tool calculates a development impact score for 10 different ecosystem services, indicating the direction and magnitude of the impact on each assessed service as well as all services combined over a 25 year timescale post-development. The user enters a range of readily and freely available indicators such as land-use changes into the tool. This information is then automatically translated into impact scores based on a quantification model which is informed by experts.	The input data required are about the proposed development site such as pre- and post-development land-use information added by the user into an Excel spreadsheet, or population density or climate. Based on that information the NCPT automatically calculates a score for each of the 10 assessed ecosystem services (and all services together), indicating the direction and magnitude of the impact of the proposed land-use changes on the value of ecosystem services. The scores are based on expert knowledge already coded into the tool.	Site scale, Local scale	http://ncptool.com/
ORVal	It is a freely accessible web-based tool that predicts the number of visits to existing and new greenspaces in England, and estimates the welfare value of those visits in monetary terms. It is based on an econometric model of recreational	All input data is provided internally by the tool – the user just has to choose an existing green space by clicking on the map, or specify the land cover of altered or newly created green space. The user can zoom into a map of England (based on OpenStreetMap)	Site scale, Local scale, Landscape scale,	http://leep.exeter.ac.uk/orval/

	demand derived from MENE data. Users can examine the recreational value of existing green space and test how the number of visits and the value of these visits might change if the land cover was changed, or if new green spaces were created. Results can be grouped by local authority area or catchment, and can be split by socio-economic group.	showing existing green spaces (allotments, cemeteries, country parks, golf courses, nature areas, parks, woods and beaches), paths and access points. The maps also show 23 habitat types from the CEH Land Cover. Designations (SSSI, Nature reserve, etc.) and points of interest (historic site, archaeology, scenic feature, viewpoint, playground) are also shown. The number of trips to each site or path segment is estimated via an econometric model based on data from the last seven years of the weekly MENE (monitor of engagement with the natural environment) survey, taking into account socio-economic characteristics, location, size, land covers, water margins, designations and points of interest. The value of the trips is based on the travel cost, in terms of vehicle fuel and travel time.	Regional scale	
PGIS (Participatory GIS tool)	The PGIS tool is an interactive website that the public can use to record their perceptions about the natural environment of the Morecambe Bay area. It captures simple information about the user and seeks to identify the locations where people experience cultural ecosystem services, and ascertain why they are important or valuable.	The input data required are personal user information, user-added pins on the online maps, descriptions of places they value and photographs or evidence. So, any particular data is required, just user opinion. Information can be gathered through workshops or surveys, or through a web-based tool such as the prototype ADAS PGIS tool. On the website, users place digital pins onto Ordnance Survey and satellite maps to show locations where they experience cultural services, noting whether the pin applies to an exact location or the general area. They can record notes and upload photos to indicate the activities they undertake there and why they find that place special. This dataset can then be layered with other map data in a GIS (e.g. land cover, site designations, rights of way) to identify correlations and areas that provide multiple ecosystem services.	Local scale, Landscape scale, Regional scale	http://web1.adas.co.uk/pgis/
SENCE (Spatial Evidence for Natural Capital Evaluation)	It provides maps, diagrams and reports to support evidence-based decision-making on ecosystem services in a spatial context. It is based on the concept that the capability of an area of land to deliver ecosystem services depends on factors including habitat, soil and geology, landform and hydrology, how land is managed and how it is culturally understood. The tool is intended to be used to help decision-makers understand	The input data required is GIS datasets (existing spatial data). Other data sources such as earth observation and remotely sensed data can be used. The first step is to construct a Habitat Asset Register: a GIS habitat map linked to a table which shows how well different habitats provide each ecosystem service. This is then combined with spatial datasets of biophysical indicators such as geology, soil, topography and hydrology. “Rule bases” are used to	Local scale, Landscape scale, Regional scale, National scale,	http://www.envsys.co.uk/sence/

	the impact of land management decisions on ecosystem services.	assign scores to these indicators that reflect their impact on each ecosystem service. For each service, a raster map showing the ability of each grid square or pixel to provide the service is created by combining and sometimes weighting the scores for the relevant factors using raster mathematics. This gives a series of maps showing the current provision of ecosystem services, the opportunities to increase provision through management interventions, and the areas where ecosystem service provision is at risk.	Multi-scale	
TESSA	It is an easy-to-use workbook that leads the user through the steps needed to assess the ecosystem services provided at a particular site. It is built around a comparison of the site in two alternative states, e.g. before and after restoration or conversion, and encourages a high level of stakeholder engagement.	Data gathered by the user for the site being assessed. Thus, habitat map of the site under current and alternative conditions. Other data requirements depend on the services being assessed and the methods being applied. The toolkit is based on an interactive pdf document which leads the user through a simple step by step approach to assess the main ecosystem services provided by the site. Preliminary guidance helps the user to select a suitable site, define the exact questions to be addressed, engage the relevant stakeholders and find out about the local political and socio-economic context. A decision tree helps the user to choose the most suitable method, given the available data and resources. Electronic links take the user to separate short pdfs which describe how to apply each method, and there are also links to additional guidance documents and case studies.	Site scale Local scale	http://tessa.tools/
Viridian	It is an in-house tool run on a consultancy basis that shows what type of habitat to create and where to create it in order to provide nature-based solutions to local problems. It splits ecosystem services into two categories: water-flow services (flooding, water pollution, erosion and drought reduction) are modelled mathematically, and place-based services (all others such as recreation and carbon sequestration) are modelled using simple GIS data layers and rules. The output maps show how to maximise ecosystem service benefits, habitat connectivity and return on investment, in order to tackle problems such as meeting water quality targets and providing	The input data required are Maps / GIS data (sourced and managed by Viridian or provided by user). Viridian can use a variety of datasets, so there is no absolute data requirement for all objectives. Viridian can use a variety of open source, commercial or client datasets. It first ranks each 5 metre pixel across the study area for its current and future ability to solve water-flow problems, using a set of algorithms. It then identifies ability and opportunity values for place-based services, such as recreation and air quality. Finally, the water-flow and place-based services are combined to show trade-offs, synergies and options for improvement. The platform provides raster map outputs that	Local scale, Landscape scale, Regional scale	https://viridianlogic.com/

	natural flood management.	indicate where habitat creation will offer the greatest benefits in a study area, including maximising return on investment and habitat connectivity.		
EST (The Ecosystem Services Toolkit)	It is a PDF format guidance document that consists of a set of steps for conducting ES assessment, as well as an extensive compendium of available analytic tools and methods and data sources that might be applied (Value of Nature to Canadians Study Taskforce, 2017). Each step includes guidance as well as templates such as worksheets that can assist with the completion of the step. In addition to the step-by-step guidance, the EST includes a typology of ES with descriptions of each one; discussion of cross-cutting issues (such as scale and uncertainty); guidance on conducting ES assessment with Indigenous communities (it is the only such toolkit reviewed with specific guidance on this issue); discussion of approaches to both economic valuation and sociocultural valuation, and resources such as tables of possible ES indicators to support analysis, guidance on approaches to valuation, and a compendium of factsheets describing data sources, and analytic methods and tools relevant to ES assessment.	The data sources for the analysis can include censuses, databases, peer-reviewed publications, non-peer-reviewed but reputable "grey" literature and reports, meeting minutes, websites, maps, and remotely sensed data. The EST advises users to start by defining the question that is driving their need for an assessment and to choose indicators, data and analysis methods to answer that question in a relevant and credible way (a problem-oriented approach). In addition, the EST contains advice about how to integrate ES assessment results and other ES considerations into the established practices associated with a wide range of policy and decision contexts.	Local to global	http://publications.gc.ca/site/eng/9.829253/publication.html
MIMES (Multiscale Integrated Model of Ecosystem Services)	It is a suite of linked economic and ecological models. It is extremely versatile and can incorporate temporal (time series) and spatial (GIS) data to simulate ecosystem and economic dynamics through space and time. Stakeholder input is used to define demand for ES. MIMES can be used to model any ES; the accuracy of model output is determined by the availability of appropriate input data.	The MIMES use input data from GIS sources, time series, etc. to simulate ecosystem components at under different scenarios defined by stakeholder input. MIMES uses scenarios to forecast how different actions affect the distribution of ES benefits in the future. MIMES can be used to compare scenarios, such as different land use, hydrology, or climate scenarios, to evaluate the implications for the provision of ES and determine trade-offs between services, as well as impacts	Local to regional	http://www.affordablefutures.com/orientation-to-what-we-do
SolVES (Social Values for Ecosystem Services)	It is a GIS application for assessing, mapping, and quantifying the social values of ES. SolVES derives a quantitative, 10-point, social values metric, called the Value Index, from a combination of spatial and non-spatial responses to public value and preference surveys. It uses these data, together with user provided environmental data, to model the spatial	Using SolVES requires having capacity to design and conduct a survey to elicit social value information from a target population. In addition to requiring a social survey, running SolVES requires specifically formatted data (e.g. survey data coding). In terms of data requirements, the main requirement is primary data from a social survey, including value allocations and	Local to regional	https://www.usgs.gov/centers/gecsc/science/social-values-ecosystem-

	distribution of cultural ES provision across a region or landscape. The ES that can be assessed using SolVES depend on the socialvalues typology used in the public value and preference survey but have commonly included aesthetic appreciation, recreation, spiritual experience and identity, learning, and future/bequest value.	associated point locations. The Value Transfer Tool allows a previously developed model to be applied to a physically and socially similar area, but this is only an option if a suitable model happens to be available for transfer. Other input data include the environmental (GIS) data layers used to represent key features of the landscape that the model uses to explain the presence of point values; these can vary from widely available land cover or elevation data to user-derived data layers such as slope, distance to water, roads, trails, or historic sites.		services-solves?qt-science_center_objects=0#qt-science_center_objects
ESII (Ecosystem services identification and inventory tool)	The Ecosystem Services Identification & Inventory Tool, or the ESII Tool, is an iPad app and web interface that lets people understand the benefits that nature provides and incorporate the value of nature into decision making.	There is not specific data required for this tools. Using the ESII Field App, you can download mapping for your property, go into the field and collect spatially-explicit ecological data for your site. In the ESII Project Workspace, you can review and edit the data once you have returned from the field, run the ESII Tool's ecological models, and generate results in a variety of user-friendly formats.	Local	https://www.esiitool.com/
CITYgreen	CITYgreen is a Geographic Information System (GIS) software program for mapping, measuring and analysing a number of different characteristics associated with green infrastructure in urban areas. These include storm water dynamics, summer energy savings, carbon storage and sequestration, air quality, and wildlife. The program enables the user to carry out complex analysis of the economic benefits of urban ecosystem services and to create clear, easy-to-understand reports that can be used for presentation in the planning process. The software can help communities determine what amount and type of green infrastructure is needed to meet sustainability objectives.	CITYgreen is as an extension for ArcGIS software and requires the user to supply land cover data in the form of aerial photography or satellite imagery. The software is provided by American Forests. The software calculates dollar benefits for the services provided by trees and other green space in your specific area.	Local	https://www.americanforests.org/our-work/community-releaf/
ESTIMAP	GIS-based model to map ecosystem services in the European Union'. The paper introduces the Ecosystem Services Mapping tool (ESTIMAP), a collection of spatially explicit models to support the mapping and modelling of ecosystem services at European scale. Its main objective is to support EU policies with spatial information on where ecosystem services are provided	ESTIMAP departs from land cover and land use maps to which it adds other spatial information with the objective to map various ecosystem services. Scenario assessments are realized by coupling ESTIMAP to a dynamic land use model (LUMP, Land Use Modeling Platform). ESTIMAP consists of a set of separate components, each of which can be run separately. At present, three modules are	Local to regional	https://ec.europa.eu/jrc/en/publication/estimap

	and consumed.	operational and described in further detail in this report: pollination, recreation and coastal protection.		
QUICKSCAN	The QUICKScan software tool is a spatial modelling environment to combine expert knowledge with spatial and statistical data. Results are visualized in interactive maps, summary charts and trade-off diagrams. There is a variety of linkable rule types ranging from qualitative knowledge matrices and Bayesian Belief Networks to include uncertainties, to multi criteria, indicator standardization and sustainability limit tools. QUICKScan can show how a result is reached by visualising the chain of knowledge and the data, for any specific location in your study area	The input dare required are raster GIS maps. QUICKScan is a participatory modelling method that links stakeholder- and decision maker knowledge and preferences to available spatial and spatial-statistical data, and is designed for group use. During such workshops an iterative approach is followed, starting with simple (knowledge-based) rules and step-by-step adding complexity, using the participants' interpretation of model-results.	local to regional	http://www.quickscan.pro/
LEFT (Local Ecological Footprinting Tool)	For a chosen area, the LEFT tool assembles relevant environmental data from global databases. Within minutes, it produces a map displaying a simple index of ecological risk.	The LEFT tool uses algorithms formulated by researchers at the University of Oxford to assess the pattern of ecological features across a chosen area. These algorithms calculate the ecological risk index. A user defines an area of interest anywhere in the world using a web-based map and LEFT automatically processes a series of high-quality datasets using standard published algorithms to produce. These results are aggregated to produce a single map of relative ecological value. The tool then generates a customised pdf report and a zip file of GIS data for the area requested. Results are delivered to users by email within a few minutes of job submission. This tool has been designed to be highly intuitive to use, and requires no specialized software or user expertise.	Local to regional	https://www.left.ox.ac.uk/
mDSS (mulino Decision Support System tool)	The mDSS software is a generic indicator-based Decision Support System (DSS) developed to assist decision makers in the participatory management of environmental problems by applying several Multi-Criteria Analysis Methods and Group Decision Making.	There is no specific data requirement. It supports Decision/Policy Makers in instances where there are choices to be made between alternative options for environmental management with the involvement of multiple actors. Based on the DPSIR conceptual framework (Driving forces-Pressures-State-Impact-Response), the methodology facilitates the integration of environmental, social and economic concerns to express preferences in terms of options sustainability with consideration of alternative exogenous scenarios drivers.	Global, Continental, Sub-continental, National, Subnational, Local	http://www.netsymod.eu/mdss/
The Green	Green Factor is a practical and user-friendly Excel-based tool	The input data required to start are the basic data about the lot,	Local	http://www.in

factor Tool	for urban planning. It ensures sufficient green infrastructure when building new lots in a dense urban environment.	such as Block and Lot ID. Additionally, some boundary conditions have to be specified: land use, type of yard, drainage system, surrounding region, soil/groundwater and Storm water management solutions. The site's area, building footprint and floor area are essential for the calculation and should be entered as accurately as possible. The Green Factor is calculated as the ratio of the scored green area to lot area. The target level for the lot can be achieved flexibly by the garden designer by selecting some of the 39 green elements, such as planted and maintained vegetation or various run-off water solutions, when designing the lot. The green factor can, for example, be included in the zoning regulations or used for granting concessions during a construction permit application process.		tegratedstormwater.eu/material/green-factor-tool
GIST (The Green Infrastructure Scenarios Tool)	The tool focuses on one watershed within the District – the Kinnickinnic River Watershed – which is located mostly within the city of Milwaukee and which is one of the most densely populated and highly paved neighbourhoods of the city.	There is no data input requirement. It combines data of 40 datasets, included NOAA, USGS, NASA, EPA and others. User ability to create scenarios: amount of investment in green infrastructure over time, mix of green infrastructure invested in, expectations about the effectiveness of green infrastructure types, amount of investment in grey infrastructure over time, future precipitation scenarios. Outputs: Measures of system performance including annual number of overflow events and basement flooding, Capital and operations costs, Co-benefits, including jobs, property values, beach closures, water quality, and energy savings.	Local	https://www.climateinteractive.org/tools/milwaukee-green-infrastructure-scenarios-tool/
SWC (EPA's National Stormwater Calculator)	It is a software application that estimates the annual amount of rainwater and frequency of runoff from a specific site. Estimates are based on local soil conditions, land cover, and historic rainfall records. It is designed to be used by anyone interested in reducing runoff from a property, including site developers, landscape architects, urban planners, and homeowners.	The SWC accesses several national databases that provide soil, topography, rainfall, and evaporation information for a chosen site. The user supplies information about the site's land cover and selects low impact development (LID) controls they would like to use. The LID controls include seven green infrastructure practices.	Local	https://swcweb.epa.gov/stormwatercalculator/
The National Green Value Calculator	It is a tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional storm water practices.	The GVC is designed to take you step-by-step through a process of determining the average precipitation at your site, choosing a storm water runoff volume reduction goal, defining the impervious	Local to national	http://greenvalues.cnt.org/national/calcu

		areas of your site under a conventional development scheme, and then choosing from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way. The input data required are relatives to lot information (Site size, Site Hydrologic Soil Group, Site location), predevelopment (Site predevelopment conditions, meaning either the state of the site before a particular project is built, or the pre-human development condition of the site), Runoff Reduction Goal, Conventional Development (Conventional development site conditions, including roof size, parking lot area, and street, sidewalk, and driveway area) and Green Improvements (Green Infrastructure BMP options).		lator.php
SWMM (Storm Water Management Model)	It is used for single event or long-term simulations of water runoff quantity and quality in primarily urban areas–although there are also many applications that can be used for drainage systems in non-urban areas. It is used throughout the world for planning, analysis, and design related to stormwater runoff, combined and sanitary sewers, and other drainage systems.	The only data required are the technical (hydraulic system, etc..) and physical conditions (exe: presence of catchment site) of the site investigated. SWMM provides an integrated environment for editing study area input data, running hydrologic, hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded drainage area and conveyance system maps, time series graphs and tables, profile plots, and statistical frequency analyses.	Local to national	https://www.epa.gov/water-research/storm-water-management-model-swmm
Twitter GI	Twitter GI - Twitter dashboard focusing on the graphical displayed behind the distribution of tweets about GI (Green Infrastructure)	There is no data requirement. Each tweet has the capability to include geographic metadata indicating the location where the tweet was authored	Local	http://www.factest.ie/london/
Aalborg heat mapping application	WebGIS viewer focusing on mapping the distribution of energy consumption	There is no data requirement. It provides web-map that illustrate data on material and energy use in the city.	Local	http://www.factest.ie/aalborg/index.html
UHI Project (Urban Heat Island)	This Decision Support System (DSS) is a software that can be used by an end user interested in the implementation of mitigation measures for counteracting UHI phenomenon.	The DDS interacts with the external user via a graphical user interface: requires the entry of certain inputs and returns the required output in the form of a text document. The input data are the scale of intervention (urban Scale of intervention Building, Urban), Typology of intervention (Existing structure, New construction, Facades, Roofs, Surface lots, Urban structure, Urban green), Economic assessment (mq, €/mq), Skills	Local	http://www.eu-uhi.eu/

		(Meteoclimatology, Biometeoclimatology, Urban planning, Health, Municipality, Innovation, Engineering, Building skill, Environment, Communication).		
Opinion Barometer	Online tool for collecting information and opinions in the course of introducing new UGI approaches and doing UGI transition projects	The tool can engage a diverse range of interested users such as local authorities, building owners or local community involved in the management and maintenance of green spaces.	Local	http://barometer.turas-cities.eu
APST (Adaptation Planning Support Toolbox)	This toolbox supports local policymakers, planners, designers and practitioners in defining the program of demands, in setting adaptation targets, in selecting from more than 60 blue, green and grey adaptation measures and with informed co-creation of conceptual adaptation plans.	The APST provides quantitative, evidence-based performance information on (cost)effectiveness of adaptation measures regarding climate resilience and co-benefits. The input data are the technical information of the project and physical condition of the site, such as adaptation target, land use, dominant soil type, surface level and slope, scale, project type and climate information.	Local	https://www.deltares.nl/publication/adaptation-planning-support-toolbox-measurable-performance-information/
VELMA	VELMA – Visualizing Ecosystems for Land Management Assessments – is a spatially distributed, Eco hydrological model that links a land surface hydrology model with a terrestrial biogeochemistry model for simulating the integrated responses of vegetation, soil, and water resources to interacting stressors. VELMA can be used to help improve the water quality of streams, rivers, and estuaries by making better use of both natural and engineered green infrastructure (GI) to control loadings from nonpoint sources of pollution. It is designed to help users assess green infrastructure options for controlling the fate and transport of water, nutrients, and toxics across multiple spatial and temporal scales for different ecoregions and present and future climates.	There is no data requirement. You have to specify the characterises, and the parameter, of the site: elevation in meters, cover species, cover species age in year, soil parameterization, precipitation mm, air temperature. Compare the effects of GI and climate scenarios on water quality and associated co-benefits and trade-offs for other ecosystem services. GI applications for essentially any region and set of conditions. It use as a common framework to compare GI strategies across ecoregions, habitat types and biophysical conditions.		https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20
Green Infrastructure Prioritization Tool	PAG created this map to help municipalities, non-profits, and neighbourhood groups to select priority locations that would benefit the most from increased access to tree shade to reduce heat exposure. This tool was additionally created to help decision-makers distribute green infrastructure resources to	There is no data required. You can select multiple layers and explore the relationships between environmental conditions and social demographics. Available data layers include regional tree canopy, surface temperature, extreme heat vulnerable populations, USDA food deserts, Tucson Bikeways and water flow		https://gismaps.pagregion.com/PAG-giMap

	areas with opportunities for enhanced storm water management, mobility and livability.	lines.		
NYC Green Infrastructure Co-Benefits Calculator	The Co-Benefits Calculator is a free tool developed by the New York City Department of Environmental Protection and allows the user to quantify and compare costs and co-benefits of common green infrastructure used in New York City	The input data required are the specifics of green infrastructure reject, such as lifespan, number of trees, number of species, m2 interested, etc. By altering some parameters, it may be useful outside of New York City. A few examples of co-benefits captured by the tool include increased property value, improved quality of life, carbon sequestration, and supported green jobs.	Local	http://www.nycgicobenefits.net/
AUTOCASE	Autocase software tool that models the environmental and social dollar values of green infrastructure designs and, together with financial costs, evaluates their net, triple bottom line (TBL) benefit over the life of a project using a rigorous cost-benefit analysis (CBA) framework. This software was developed with the goal of optimizing lifecycle costs of a project. In focusing on a lifecycle cost analysis that incorporates not only economic but also social and environmental factors, Autocase presents a holistic approach which may help justify the costs of green infrastructure over traditional grey infrastructure.	The software allows the user to input site-specific design information and pulls from compiled database information (e.g., Census information, meteorological data, etc.). The software allows to input a range of values and run a Monte Carlo simulation of the Triple Bottom Line Cost Benefit Analysis (TBL-CBA) model. This software also offers a concise way to communicate the many goals of green infrastructure techniques.	Local	https://autocase.com/
HEAT (Health Economic Assessment Tools)	The Health Economic Assessment Tools (HEAT) for walking and cycling are tools from the World Health Organisation Regional Office for Europe. The HEAT tool is designed to enable users without expertise in impact assessment to conduct economic assessments of the health impacts of walking or cycling. The tool is based on the best available evidence and transparent assumptions. It is intended to be simple to use by a wide variety of professionals at both national and local levels. These include primarily transport planners, traffic engineers and special interest groups working on transport, walking, cycling or the environment.	They assess health benefits and are not specific to a certain type of green infrastructure feature. The benefit of these recreation activities is measured through reduced mortality. The HEAT estimates the value of reduced mortality that results from specified amounts of walking or cycling. You have to enter your data on travel modes and to specify the unit, the actual amount, and the type of population it applies to. The amount must be per person, per day. The population data (age range and number of subjects) typically refers to the general population - but you can specify whether your data refers to cyclists or pedestrians only.		https://www.heatwalkingcycling.org/#homepage
R3 UrbanTools	R3 UrbanTools allows to manage in an integrated way the topographic database (DBT), the cadastre, the urbanistic tools and the addresses, extracting from each database the relevant information for the purposes of administrative procedures, urban and tax inspections also. R3 UrbanTools allows to record	Data requirement is various. It needs cartographic data and municipal datasets, tax datasets, civic information and thematic GIS maps about green space, idraulic systems and others. The tool allows to mange all this information in a unique dataset and unique graphic interface	Local, city, urban and periurban	https://www.r3-gis.com/it/r3-urbantools

	the modifications of the cartography as a result of building interventions or public works, triggering a procedure of continuous updating of the topographic database. It is a tool based on WebGIS technology, which allows you to manage all this information through a simple interface.			

Annex A3. Tools for ecosystem services valuation at urban level – case studies

Tool	Location	ES	Input/data	Ec. valuation	Methodology used	Valuation included	Comments	Bibliography
APST (Adaptation Planning Support Toolbox)	Utrecht The Netherlands 2005	Water quantity regulation (reduction of run off); Heat stress reduction	Water storage capacity and meteorological data; Local cooling of the measure and surface area	N.A.	N.A.	NO	Results are in terms of effectiveness of the measure.	Frans Van de Ven, F., Bosch, P., Brolsma, R., Keijzer, E., Kok, S., Van der Meulen, S., & Vergroesen, T. (2016). Green, comfortable, attractive andclimate resilient Utrecht Centre-West area : SSD - Deep Dive Utrecht Opportunity 3. *Delatres*.
ARIES (ARtificial Intelligence for Ecosystem Services)	Puget Sound USA 2006	Flood regulation for developed land in 100 year floodplain; Homeowner proximity to open space; Scenic view sheds for homeowners	Data on tree canopy cover, hardwood to softwood ratio, successional stage, land cover/vegetation type, hydrologic soils group, impervious surface, and location of housing	For the managed land use change scenario, ecosystem service flows for flood regulation increase by 56%, of open space proximity by 25.2% and of scenic view shed by 18.5%; for the unmanaged land use change scenario, flows for flood regulation increase by 55.7%, of open space proximity by 23.2% and of scenic view shed by 31.7%	N.A.	YES	With respect to ecosystem services of vegetation and soil carbon storage and sediment retention, only their changes in natural stock were computed, but not their changes in flows.	Zank, B., Bagstad, K. J., Voigt, B., and Villa, F. (2016). Modeling the effects of urban expansion on natural capital stocks and ecosystem service flows: a case study in the Puget Sound, Washington, USA. *Landscape and Urban Planning*, *149*, 31-42.

BeST (Benefits of SuDS Tool)	Zwolle The Netherlands 2007	Cultural (health, education, amenity); regulating (climate, carbon, flooding); and supporting (biodiversity)	N.A.	€ 367.000	Hedonic pricing (amenity value); Avoided cost methods (education, health, and flooding); Benefit transfer (biodiversity); Marginal cost (carbon sequestration)	YES		Ashley, R. M., Gersonius, B., Digman, C., Horton, B., Bacchin, T., Smith, B. & Baylis, A. (2017). Demonstrating and monetizing the multiple benefits from using SuDS. *Journal of Sustainable Water in the Built Environment*, *4*(2), 05017008.
CITYgreen	Wellington 2005	Air pollution removal; Water quality (runoff)	Data on current pollutant figures and monetary value of the pollutant removed per unit area of canopy; terrain slope, runoff rates, hydrological soil type, rainfall and dollars per unit of constructing a storm water facility to manage additional peak storm water runoff volume that would be created by removing trees from a study site.	Monetary valuation of air pollutant removal amounts to US$ 851114, whereas storm water savings are US$22256461	Market prices (air pollution removal); Damage avoided costs (water runoff)	YES	It also provides ton per year of carbon sequestered and percentage change in water contamination, although no economic valuation of these two ecosystem services is provided	Kingston, R., Cahill, D., Handley, J., Tzoulas, K., and James, P. (2008). Toward a Green Infrastructure valuation model: Assessing the potential for the CITYgreen GIS software for use as a tool for qualifying the economic benefits of Green Infrastructure in the UK.

Co$ting Nature	Southern Ontario Canada 2017	Water provisioning and supply; water quality; carbon sequestration; carbon storage; flood regulation; nature-based tourism (including recreational and aesthetic value)	Global databases of GIS data (no local input data were needed)	Contributions to the total potential value are as follows: flood regulation accounts for CAD$7.98 billion/year; water quality for CAD$4.89 billion/year; carbon storage for CAD$4.05 billion/year; nature-based tourism for CAD$1.58 billion/year; water supply for CAD$0.63 billion/year; and carbon sequestration for CAD$0.07 billion/year	Benefit transfer	NO	Co$ting Nature identifies both potential and realized ecosystem services and yields their spatial distributions on a relative scale with corresponding service indices that range between 0 and 1	Aziz, T., & Van Cappellen, P. (2019). Comparative valuation of potential and realized ecosystem services in Southern Ontario, Canada. *Environmental Science & Policy*, *100*, 105-112.
EcoServ-GIS	Cumbernauld UK N.A.	Air purification; carbon; local climate; noise regulation; pollination; water purification; accessible nature; education; green travel	Nationally available datasets	N.A.	N.A.	NO	The EcoServ-GIS toolkit generates maps illustrating the need for each service as well as the capacity for service provision	Winn, J., Mackenzie, I. & Hill, K. (2015). Mapping the benefits of nature and the green network: A new town case study. A guide for Local Authority Planners, Green Infrastructure Officers, Ecologists and Landscape Architects.
ESII (Ecosystem services identificat	Kanawha River USA N.A.	Water provisioning; water quality control; erosion control; visual	Ecological data	N.A.	N.A.	NO	ESII computes the production of each ecosystem service under the different	ESII Tool. Restoring Former Industrial Land to Benefit Nature & Community. https://www.esiitool.com/case-studies.

ion and inventory tool)		aesthetics					scenarios.	
ESTIMAP	Oslo Norway 2016	Pollination	N.A.	N.A.	N.A.	NO	Using both the literature and consultations with experts, model developers generate ES scores to express the relative suitability of land units for pollinating insects in terms of availability of both floral resources and nesting sites. Model inputs also included foraging range and an activity index that represented the effects of local climatic conditions on insect pollinator flight.	Stange, E., Zulian, G., Rusch, G., Barton, D., & Nowell, M. (2017). Ecosystem services mapping for municipal policy: ESTIMAP and zoning for urban beekeeping. *One Ecosystem*, *2*, e14014.

GI-Val (Green Infrastructure Valuation Toolkit)	St Helens UK 2005	Climate change adaptation & mitigation; Water management & flood alleviation; Health & well-being; Labour productivity; Tourism; Recreation & leisure; Biodiversity; Land management	Project area, total area of greenspace, new greenspace created, area of greenspace enhanced; Trees, cycle routes, current cycle routes upgraded, footpaths, footpaths upgraded; number of households, businesses, and residents within 300m, and within 1200m; Number of community groups involved; Local visitors, tourist visitors, working population; Area designed for nature and wildlife conservation; Number of jobs created, average residential property price in the area	£15.212 million	N.A.	YES		The Mersey Forest (2011). Stanley Bank Triangle Estimated Economic Valuation. https://www.merseyforest.org.uk/files/Valuation_stanley_final.pdf
HEAT (Health Economic Assessment Tools)	Kuopio Finland N.A.	Health benefits	A survey was used to estimate the number of people cycling and duration cycled	The current value of the average annual benefit averaged across 10 years varied between €396,000 and €7,604,000	N.A.	YES	HEAT was used to estimate the economic value of the cycling to work carried out by employees of the city council.	WHO (2013). Using the health economic assessment tools (HEAT) for walking and cycling: lesson learnt Final report.

InVEST (Integrated Valuation of Ecosystem Services and Trade-offs)	3 towns (combined urban areas) UK 2007-2010	Carbon storage; sediment erosion; pollination	Data identifying the carbon storage capability in carbon pools for each land cover class in the map; Data on topography, climate, soil and land cover properties; Data on nesting and foraging parameters for multiple pollinator species or species groups, along with nest and flower availability by land cover type for a landscape	N.A.	N.A.	NO	InVEST computes the total potential capacity of each ecosystem services through models, without providing an economic valuation.	Grafius, D. R., Corstanje, R., Warren, P.H., Evans, K.L., Hancock, S. & Harris, J.A. (2016). The impact of land use/land cover scale on modelling urban ecosystem services. Landscape Ecology. Online first 1-14.
i-Tree (previously UFORE)	10 cities USA 1996-1999	Carbon sequestration	Data on location, species, stem diameter at 1.37 m above the ground, tree and crown height, crown width, and canopy condition	Urban trees in the USA currently store 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million tC/yr ($460 million/year)	Market prices	NO	The tool is used to estimate total biomass. fresh-weight biomass was multiplied by species- or genus-specific-conversion factors to yield dry-weight biomass. Total tree dry weight biomass was converted to total stored carbon by multiplying by 0.5.	Nowak, D. J., and Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental pollution*, *116*(3), 381-389.

LAP (Local Action Project - Local Action Toolkit)					N.A.	NO	The benefits wheel shows you the relative contribution a certain type of intervention can make to a specific characteristic of an area	N.A.
NCPT (The Natural Capital Planning Tool)	Birmingham UK 2016	Harvested products; biodiversity; Aesthetic values; recreation; Water quality regulation; Flood risk regulation; air quality regulation; local climate regulation; global climate regulation; soil contamination	N.A.	N.A.	N.A.	NO	The NCPT calculates minimum/maximum scores, which indicate the potential of the site to both lose and gain natural capital	Hölzinger, O., Sadler, J., Scott, A., & Grayson, N. (2019). NCPT–managing environmental gains and losses. *Town & Country Planning*, 167.

ORVal	West Norwich UK N.A	Recreational value	N.A.	This complex of greenspaces attracts an estimated 891,872 visits each year creating a welfare benefit of approximately £2,600,000.	N.A.	YES		Day, B., and Smith, G. ORVal Short Case Study 1: Valuing Recreational Sites in West Norwich (Version 2.0). https://www.leep.exeter.ac.uk/orval/pdf-reports/casestudy1_selection.pdf
QUICKScan	Glenlivet UK N.A	Timber provision, wader bird habitat provision, recreational fishing, recreational hiking and cattle grazing	10x10 m resolution: land cover, topographical wetness, accessibility, elevation, distance from rivers, administrative units and topography	N.A.	N.A.	NO	The QUICKScan software tool is a spatial modelling environment to combine expert knowledge with spatial and statistical data. Results are visualized in interactive maps, summary charts and trade-off diagrams.	Dick, J., Verweij, P., Carmen, E., Rodela, R., & Andrews, C. (2017). Testing the ecosystem service cascade framework and QUICKScan software tool in the context of land use planning in Glenlivet Estate Scotland. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *13*(2), 12-25.
SWC (EPA's National Storm water Calculator)	12 cities USA 2010-2015	Water runoff	N.A.	N.A.	N.A.	NO	SWC is a software application that estimates the annual amount of rainwater and frequency of runoff from a specific site.	Schifman, L. A., Tryby, M. E., Berner, J., & Shuster, W. D. (2018). Managing uncertainty in runoff estimation with the US Environmental Protection Agency national stormwater calculator. *JAWRA Journal of the American Water Resources Association*, *54*(1), 148-159.

SWMM (Storm Water Management Model)	Genova Italy 2007-2008	Storm water run off	N.A.	N.A.	N.A.	NO	It is used for single event or long-term simulations of water runoff quantity and quality in primarily urban area	Fioretti, R., Palla, A., Lanza, L. G., & Principi, P. (2010). Green roof energy and water related performance in the Mediterranean climate. *Building and environment*, *45*(8), 1890-1904.
The National Green Value Calculator	Houston N.A.	Run off reduction	N.A.	The total annual benefits that LID offers are $1106, while the total life-cycle benefit is $35,050 more than conventional storm water management	N.A.	YES		Thiagarajan, M., Newman, G., & Zandt, S. (2018). The projected impact of a neighborhood-scaled green-infrastructure retrofit. *Sustainability*, *10*(10), 3665.