The Nature Smart Cities Business Model

Handbook part two:

Technical manual

Interreg
EUROPESE UNIE
2 Seas Mers Zeeën

NATURE SMART CITIES
ACROSS THE 2 SEAS

About this manual

This is the second of two volumes describing the operation of the Nature Smart Cities Business Model. The Business Model is a tool intended to help with the preparation of a convincing business case for a green infrastructure solution, and is based on extensive research both within academic literature and also with officers and practitioners in smaller municipal authorities in the UK, France, Belgium and the Netherlands.

The first volume is a step-by-step guide to using the model, and can be downloaded, free of charge, from the Nature Smart Cities website library at www.naturesmartcities.eu/library

About the authors

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About the project

Nature Smart Cities is a project funded by the European Union through its Interreg 2 Seas programme. The project brings together city partners from Belgium, the Netherlands, France and the UK, and academic partners from the Universities of Ghent and Antwerp, and Imperial College London, to work together on maximising the potential for smaller cities to engage more fully with nature-based solutions to environmental problems, using green infrastructure. The project is funding several pilot projects exploring green infrastructure solutions in smaller cities, and is also developing a business model aimed at helping officers in smaller cities to make a stronger business case for green solutions, both in terms of ecosystem service delivery and also financial comparison with more traditional approaches. The project is described in more detail at www.naturesmartcities.eu

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Contents

1. Introduction

The goal of this Technical Manual is to provide you with background on the development and content of the Business Model.

Common terms used in this guidance

Green infrastructure (GI): the use of natural materials and landscapes, rather than man-made materials such as concrete, to address structural needs in the community. For instance, the use of grassed banks and drainage channels to contain flood water, rather than concrete walls and troughs.

Grey infrastructure: the man-made alternative to a green solution. Or an impermeable material, such as slate, tiles tarmac, paving stones and so on.

Project: An idea the local authority wishes to pursue, to achieve a desired result.

Scenario: one of perhaps several different ways in which a project can be achieved. The project will always be constant, but a number of different ways of doing it can be suggested – these are the scenarios.

1.1. The Business Model

The Business Model created within the Nature Smart Cities (NSC) project is a methodology that aims at assisting decision makers in understanding the benefits and costs of GI projects. It provides them with a tool to demonstrate how a GI project can generate returns (qualitatively, quantitatively, monetarily) and how the returns compare to the more typically chosen grey infrastructure. It can also be used to compare alternative new approaches.

The Business Model is based on evidence that the University of Antwerp, Ghent University, and Imperial College London collected through interviews with local authorities and analysis of geographical, biophysical, and economic data. The Business Model on GI projects is tested, refined, and validated through interaction with seven GI pilot investments in Southend-On-Sea, Cambridge, The Hague, Kapelle, Antwerp, Bruges, and Lille, and has been tested in several other authorities and refined as a result.

The Business Model provides pragmatic methods to value the costs and benefits of an intended GI project. The benefits are analysed in terms of ecosystem services (ES), and the results can then be used to formulate a business case for a green approach.

It consists of four parts:

- this technical manual,
- a step-by step guidance manual
- a multi-criteria analysis (MCA) tool (in Excel),
- a factsheet which summarises the outcomes of the MCA.

The **technical manual** (this document) explains more about the background to the model, the theory and evidence that underpins it, and its provenance in peer-reviewed academic literature.

The **step-by-step guidance** is a hands-on guide to using the model, in the detail that a new user would find helpful.

The **MCA tool** provides a comparative and structured overview of the advantages and disadvantages of specific GI options. Typically, different design options, referred to as scenarios, are compared in an MCA. The comparison is based on several evaluation criteria, hence the name multi-criteria analysis. It combines data from qualitative assessment, quantitative calculations, and monetary calculations to present a comprehensive picture of each scenario being considered.

A MCA is a flexible, adaptable, and responsive, method that embraces the multi-functionality of green infrastructure. This method serves perfectly to compare grey infrastructure with green infrastructure, and even include hybrid solutions, and also to compare alternative green solutions. It can also be used as a design tool, allowing the user to modify their data and see the effect these changes have on the outcome.

The criteria that populate the model are selected by the local authority (LA), structured around the ecosystems that the authority wishes to prioritise in its project. The thorough assessment of each scenario for each of the criteria is the core of the Business Model.

The results of the MCA will be transferred into a **factsheet**, generated in and from the MCA analysis, and presented in an accessible, non-technical format that can be used to make the case for your project with a non-expert decision-maker.

Decision-makers will thus be able to value their GI project and understand the impact of GI on ES. As the same analysis process is used for each scenario put through the model, the results are consistent with one another and are directly comparable. However, **the Business Model will not generate exact numbers of costs and benefits for specific projects; it will provide estimations and guiding figures**. In other words, the Business Model is intended as an exploratory exercise to identify the potential costs and benefits of GI, or to compare different GI approaches.

1.2. Introducing Ecosystem Services (ES)

Humans use a wide range of services and raw materials provided by ecosystems. These benefits are commonly known as ‘ecosystem services (ES)’ and include products (e.g. wood, food, drinking water) and processes (e.g. decomposition of waste, drainage). They can also have cultural and societal benefits (e.g. recreation, scenic beauty, social cohesion) and economic benefits (attractors for tourism or investment, raising land values) and can support both human and other life.

Most people have long believed that ES are free, invulnerable, and inexhaustible (Hendrix, et al., 2018). This is not the case, and recognizing the value of ES is becoming increasingly important, as is working to ensure positive ES outcomes as a major contributor to the quality of life (Back and Collins, 2022).

Although there are many possible definitions and classifications of ES, this Technical Manual will follow the definition and classification of ES provided by the Millennium Ecosystem Assessment (MA), a report involving over 1300 scientists, which is broadly accepted in the academic and scientific community (Fisher, Turner, & Morling, 2009). In the report, **ES are defined as the benefits people obtain from ecosystems** (MA, 2005). The report also provides a classification of ES, namely, the supporting, regulating, provisioning, and cultural ES (see Figure 1). This classification is also used in our business model. An overview:

- **Provisioning or producing services:** The products derived from ecosystems, such as genetic resources, food, fibre, and raw materials such as wood, cane, etc.
- **Regulating services:** The benefits derived from the regulation of ecosystem processes, including the regulation of climate, water, and human diseases.
- **Cultural services:** The intangible pleasures people derive from ecosystems through mental enrichment, cognitive development, recreation, and aesthetic experience.
- **Supporting services:** These services are needed for the provision of all the above services such as soil formation, photosynthesis, food cycle, etc. (Hendrix, et al., 2018; MA, 2005)

Figure 1: *ES (Source: own composition)*

1.2.1. The value of ES

Ecosystems underpin human life and provide goods and services that contribute to our prosperity and well-being. But what is the value of these goods and services? Often it is assumed that the market price of a good or service equals its value, but the value rarely equals the price we pay. Since most ES cannot be bought or sold, it might be assumed that ES are ‘free of charge’, but this does not mean that ES have no value. In fact they do have a value, and in many cases this value can be measured in some way.

Furthermore, even those ES that are sold on a market (e.g. materials and food) do not necessarily have the ‘right’ price as a result of market failures (e.g. subsidies or environmental costs that are not reflected in the price of a certain good) (Hendrix, et al., 2018; Liekens, et al., 2013).

One of the main reasons to value an ES is the belief that it will contribute towards better and more balanced decision-making. This is achieved by ensuring that LAs fully take into account the costs and benefits of infrastructure to the natural environment as well as their implications for human well-being (Defra, 2007), whereas by failing to recognize the value of ES, LAs might make unbalanced policies and investment decisions regarding green and grey infrastructure (Liekens, et al., 2013).

Our model aims to provide LAs and decision-makers with a better insight into the value of ES provided by green infrastructure in cities.

1.2.2. Green infrastructure

Green infrastructure can be defined as **“an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations”** (Benedict & McMahon, 2006, p. 5). **Grey infrastructure,** on the other hand, refers to the **human-engineered infrastructural applications** such as roads, wastewater treatment plants, pipelines, and dams.

There are different forms and ways of bringing green space into cities. These different applications or forms can be categorized. The NSC project will follow the slightly modified categorization of urban green infrastructure as provided by the IGNITION project:

- **Green walls:** vegetation growing on or against a vertical surface (e.g. green façades, bio-responsive façades, living walls, vegetated mats and felt systems, modular living walls, vertical greening systems, hydroponic green walls, green screens, and hedges)
- **Street trees:** trees located next to or within a road or footpath
- **Low green:** Areas that are naturally or artificially covered with vegetation (e.g. grass and bushes), where water can permeate through the soil and vegetation. Can include playing fields, cemeteries, allotments, parks, roadside verges, and open or vegetated space of all types, whether managed or not.
- **Green roofs:** vegetation growing on any structure's horizontal surface
- **Sustainable drainage systems (SuDs):** involves the management of surface water runoff in a way that mimics natural drainage processes, while supporting broader biodiversity and amenity aims (e.g. water butts, rainwater harvesting, filter drains, filter (buffer) strips, swales, ponds or retention areas, wetlands, detention basins, soakaways, infiltration trenches, infiltration basins, permeable surfaces, bioretention areas, silt removal devices, and trench-troughs or wadis) (GMCA, 2020).

The different kinds of urban green infrastructure generate a diversity of ES and benefits which city residents depend on to sustain their welfare (see Figure 2 for examples). Examples of these benefits include enhanced biodiversity, better water drainage, and cleaner air, all of which are highly desirable outcomes that may contribute to overarching governmental or societal goals.

However, since the benefits and costs of green infrastructure are often challenging to calculate, LAs habitually opt for grey infrastructural solutions.

Figure 2: *Examples of urban green infrastructure*

Note: *The pictures on the first row are examples of green walls; the second row are examples of street trees; the third row are examples of low green; the fourth row are examples of green roofs; and the pictures on the last row are examples of sustainable drainage systems.*

1.2.3. ES in relation to green infrastructure

Before starting an infrastructural project, LAs or decision makers should consider if it is possible to implement green infrastructure instead of grey infrastructure, to meet the city's needs.

Table 1 gives an overview of the ES that are most likely to be achieved by implementing a certain kind of GI. In the table, the 'green label' refers to ES that are very likely to arise, 'orange label' refers to ES that might arise, and the 'red label' refers to ES that will most likely not be provided by implementing that kind of GI.

However, one should be aware that the specific ES created or enhanced through GI, as well as the amount of ES provided by GI, depend on the characteristics and scale of the GI project. For example, if a city decides to implement more street trees, they can be certain that the trees will contribute to carbon sequestration, micro-climate regulation, habitat for biodiversity, and so on, yet the quantity of ES created will depend on other variables: how many street trees are planted, which kind of trees, the location of the trees, etc.

Table 1: *The ES created by a certain type of GI*

Ecosystem services		Urban green infrastructure							
		Green wall	Single and park-related trees	Fruit and vegetables	Low green	Green roofs	Sustainable drainage systems	(semi-) permeable surfaces	Grey infrastructure
Provisioning	Food	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥
	Materials	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥
Regulating	Carbon sequestration	🟧	🟩	🟩	🟧	🟧	🟥	🟥	🟥
	Micro-climate regulation	🟧	🟩	🟩	🟧	🟧	🟧	🟧	🟥
	Noise pollution	🟩	🟧	🟧	🟧	🟩	🟥	🟧	🟥
	Water retention and infiltration	🟧	🟩	🟩	🟩	🟩	🟩	🟩	🟧
	Air filtering	🟧	🟩	🟩	🟥	🟧	🟥	🟥	🟥
Supporting	Habitat for biodiversity	🟧	🟩	🟩	🟩	🟧	🟧	🟧	🟥
Cultural	Aesthetic appreciation	🟧	🟩	🟩	🟩	🟩	🟧	🟧	🟥
	Physical and mental health	🟧	🟧	🟧	🟧	🟥	🟥	🟥	🟥
	Recreation & tourism	🟧	🟩	🟩	🟧	🟥	🟧	🟥	🟥
	Real estate prices	🟧	🟧	🟧	🟥	🟩	🟧	🟥	🟥
	Education and raising awareness	🟧	🟧	🟧	🟥	🟧	🟧	🟥	🟥
	Social cohesion	🟧	🟧	🟧	🟧	🟥	🟧	🟥	🟥
	Attracting companies and investments	🟧	🟧	🟧	🟥	🟧	🟥	🟥	🟥

Source: *(Horton, Digman, Ashley, & McMullan, 2019), (Hendrix, et al., 2018)*

Legend: *Green = ES that are likely to be achieved/improved; orange = ES that can be achieved depending on the specific type of GI and the extend of the project; Red = ES that will not be achieved/improved.*

Note: *The ES provided by GI depend on the specific kind of GI. For instance, street trees will not provide the ES 'food', unless the city chooses to plant fruit trees.*

1.3. When should you use the MCA tool?

The Nature Smart Cities Business Model provides a tool for LAs to better estimate the benefits they can secure from taking a green approach, and the costs that will arise. There are three possible starting points from which the LA can depart:

- A specific identified problem needs a solution in the form of a project. The ES you need can be identified as a desired outcome of the project, and you can use the model to compare a green solution with a grey one, or to compare different green approaches with one another.
- A project may be under consideration. It may be targeting a particular need in the city, but you may also be aware that other benefits will flow from approaching the project in a particular way.
- Or a LA may want to enhance particular ES and/or bring more nature to the city without having a specific GI project in mind or a problem they need to solve. The model can be used to design a project, and even to compare results between different locations.

Ideally LAs should use the MCA tool in the initial stage of their project, as this will allow adjustments to the design of the project if necessary. Nevertheless, the MCA tool can be used in any stage of the GI project, even after the project is finished.

When a change occurs in an ecosystem service, it is often possible to quantify the extent of this change in qualitative, quantitative and/or monetary terms. When the ecosystem service disappears, one can value the benefits of the ES that are lost. There are however problems in making these calculations, that the MCA can help overcome.

In order to better estimate the value of ES provided by GI, the MCA will allow LA to compare different scenarios. It will not only be possible to compare the baseline scenario (the situation before infrastructural changes) with a grey or green scenario (the forecast situation after making infrastructural changes), but it will also be possible to compare different GI alternatives, different gradations of green infrastructure, and even hybrid solutions combining grey and green components. Making these assessments using a consistent methodology will produce more convincing and credible results.

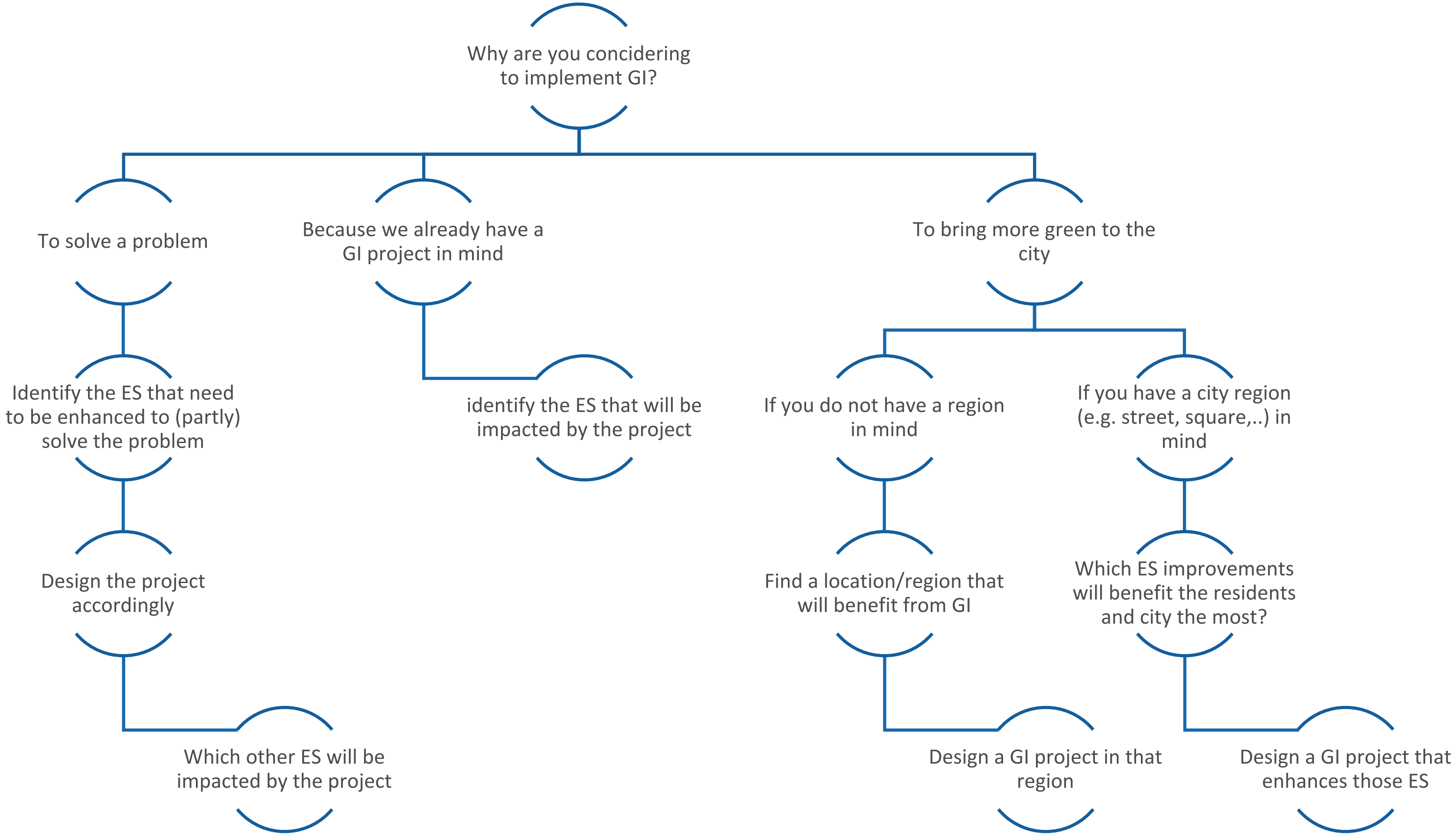


Figure 3: *Decision Tree*

2. Selecting, qualifying, quantifying, and monetizing ES

This section of the Technical Manual will explain each step of the Business Model MCA tool.

2.1. Introduction

Although the Business Model can be used during any stage of your project, we believe that the added value will be the highest when applied in the initial stages. The Business Model is based on evidence that was collected through interviews with local authorities and analysis of a wide range of peer-reviewed geographical, biophysical, and economic data.

To apply the MCA tool, you will need to gather some information:

- Information on the types and amounts of green, grey and blue infrastructure in the current scenario and (possible) future scenario(s).
- Precise information about the targeted area, these could include: number of inhabitants who will benefit, average price of a house, average annual rainfall, average price of electricity, etc. This case specific information depends on the ecosystem services you will choose to evaluate.
- Information/Estimation about the costs of your proposed infrastructural installation(s) are advised but not obligatory to use the tool, ball-park figures are provided.

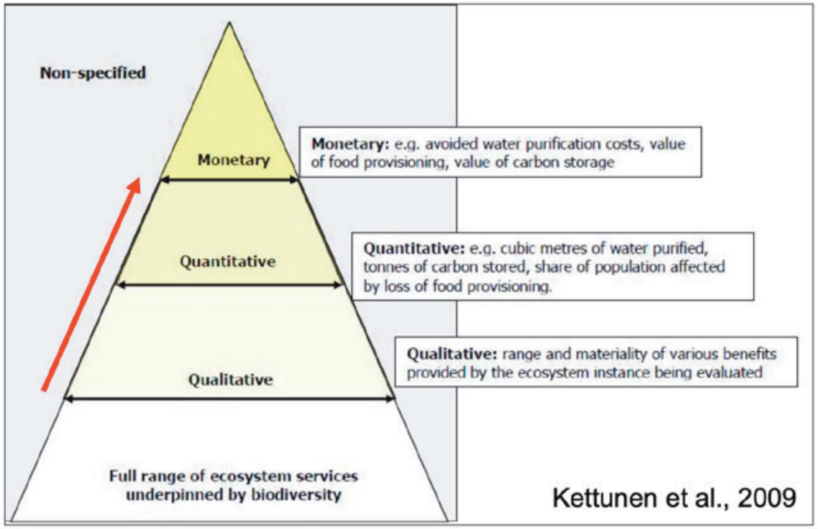
The MCA steps are based on different types of results: qualitative, quantitative, and monetary results. All ecosystem services can be seen as having qualitative potential, such as impact on human well-being. Some can be measured quantitatively, and some of these can be converted into monetary terms. The tool uses this approach, with results at each level that the ecosystem service in question permits. The hierarchy is not based on importance or significance, but rather on what is possible for each ES. This hierarchy is based on the pyramid method deployed by Kettunen et al. (2009) and illustrated by Figure 4. Attentive users will notice that the order of the pyramid has been altered in the business model itself. For pragmatic reasons, users are first confronted with the quantitative evidence (which still includes less ES information than the qualitative phase). After all, demonstrator testing showed that users felt uncomfortable and found it arbitrary to score ES qualitatively before having achieved a sense of the magnitude of some of the impacts of GI.

The Business Model tool follows this hierarchy and translates it to the following seven steps:

- **Step 0 – Project description:** Before starting the MCA, you will need to describe some important characteristics of the target area as well as the current – or baseline - scenario and one or more future scenarios.
- **Step 1 – Selection:** This step will allow you to select the most relevant ecosystem services, which will be used during the next steps of the MCA.
- **Step 2 – Parameter selection:** This step serves to gather specific information on the targeted are and green infrastructure project, which will be used for calculating the costs and benefits.
- **Step 3 – Quantification:** This step allows the user to quantify the impacts of different scenarios on ecosystem services in biophysical or quantitative terms. You can choose to use generic data (based on the parameters you provided in the previous step) or case specific data (if this is available to you, generic data can be overwritten).
- **Step 4 – Qualification:** This step allows you to compare the different scenarios using an intuitive 4-point scale to assign scores to the impact of the different scenarios on each of the ecosystem services. Give a description of the impact as argumentation of the score.
- **Step 5 – Monetization:** This step will convert the biophysical values into monetary terms. This will provide an estimation of the project's costs and benefits, both in terms of yearly streams and longer-term (20y, 40y) figures.
- **Step 6 – Factsheet:** This step gives the user an understanding of the estimated total impact of a project including green infrastructure. From this worksheet, users can compile their PDF, which is an easily interpretable and visually enhanced overview of the project.

The detailed guidance on how to complete each of these steps is provided in the step-by-step manual.

Figure 4: *the Valuation Pyramid by Kettunen et al. (2019)*



2.2. Step 0 – Project description

2.2.1. Purpose of this step

The purpose of this step is twofold. Firstly, we want to gather some general information about the targeted area and to describe the situation as it is (baseline) as well as the (possible) future scenario(s) in some detail. When we use the concept of 'scenarios', we are referring to the (various) infrastructural plan(s) you have in mind. These scenarios can contain small differences (e.g. a scenario with a park without trees vs. a park with trees) or large differences (e.g. constructing an impermeable parking lot vs. a green park). You can add, and thus compare, as many scenarios as you want, but note that the more scenarios you add, the more complicated this exercise will become. The second possible objective of this step is to describe the baseline scenario (the current situation or situation before the infrastructural changes) and other (future) scenarios in as much detail as possible. This will allow the tool to compare the different options throughout the different steps.

In this step, you define different landscape elements present in your baseline and in your various scenarios. Each landscape type has its own characteristics, in terms of (for instance) water retention capability, biodiversity potential, carbon absorption and so on. The more closely you define this, the more accurate the model's calculations will be.

2.3. Step 1 – Selection

2.3.1. Purpose of this step: Rapid assessment

A rapid assessment can be defined as "intensive, team-based qualitative inquiry using triangulation, iterative data analysis, and additional data collection to quickly develop a preliminary understanding of a situation from the insider's perspective" (Beebe, 2005, p. 285). In other words, LAs, decision-makers and/or residents can jointly decide on the ES that are important and relevant for their specific project. A rapid assessment allows LAs, and other actors involved, to discuss and organize their priorities, as well as communicating their priorities to others.

This step of the Business Model tool uses a rapid assessment to identify the most relevant ES for a specific project. Table 2 summarises the most common and relevant ES which are also used in the MCA tool.

Table 2: *Template for rapid assessment of the ES*

Ecosystem services		Description and examples	References
Provisioning	Food	This ES refers to the quantity of crops and fruits that are harvested within a certain area For instance, by implementing allotment gardens or planting fruit trees, residents can benefit from the food that is produced.	Liekens, et al., 2013
	Materials	Vegetation is a source of biomass. Biomass refers to a variation of (plant) materials such as wood, trimmings, and other vegetable residues. These materials can be used to produce energy and other products such as benches and climbing racks.	Aertsens, et al., 2012
Regulating	Carbon sequestration (global climate regulation)	This ES refers to the quantity of carbon plants absorb from the environment. This way the carbon is (temporarily) removed from the environment. For example, by planting more trees and other plants, more carbon can be captured and stored. This can contribute to climate change mitigation.	Liekens, et al., 2013
	Micro-climate regulation (global climate regulation)	Green infrastructure can have a positive microclimatic effect. On the one hand, nature can serve as a source of cooling in cities on hot (summer) days, and on the other hand, it can reduce heat losses on cold (winter) days. For example, ‘blue’ areas provide cooling and trees block sunlight, both help to keep the ground below cool during summer. Moreover, trees take up water from the ground and release it through the surface of their leaves. This also results in cooler surrounding air.	Liekens, et al., 2013
	Noise pollution	Vegetation can effectively reduce noise levels (from traffic and other sources), and can also have a positive psychological effect. For example, noise from traffic can result in health problems for people in urban areas, but by implementing vegetation the noise pollution can be mitigated.	Liekens, et al., 2013
	Water retention and infiltration	This ES refers to the fact that more nature can contribute to stable groundwater levels since water is better retained. Healthy aquatic ecosystems in turn ensure that the water levels in the waterways do not fluctuate too much. For instance, vegetated areas allow water to seep through the soil where the vegetation absorbs the water and releases it back into the air through evapotranspiration.	Liekens, et al., 2013
	Air filtering	This ES refers to the change in air quality by removing pollutants from the atmosphere, including ozone (O_3), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and, carbon monoxide (CO). Air pollution from transport, domestic heating, industry, etc. all contribute to the increase of respiratory and cardiovascular diseases in cities and by implementing more vegetation in cities, more particulate matter and toxic gases can be absorbed.	Gómez-Baggethun & Barton, 2013
Supporting	Habitat for biodiversity	Vegetated green infrastructure features can improve and expand the habitat for a wide variety of flora and fauna, which results in more plant- and animal species and thus higher biodiversity	CNT, 2011

Ecosystem services		Description and examples	References
Cultural	Aesthetic appreciation	This ES refers to the attractiveness and desirability of the area. Furthermore, these factors improve the living quality and the 'experience value' of residents.	Horton, Digman, Ashley, & McMullan, 2019 Brook, 2019 Tieskens et al., 2018 Rolston, 1995 Tribot et al., 2018 Salto, 1984 Natural England, 2009
	Physical and mental health	Physical activity (e.g. walking, running, biking, etc.) in the presence of nature leads to positive health effects in the short and long term. It also increases self-image and mood. When green encourages more exercise, this will lead to savings on health costs	Aertsens, et al., 2012 Evans et al., 2013 Thompson, 2011 James, 202 Martin et al., 2020
	Recreation, and Tourism by external visitors	There are various forms of recreation and tourism. In addition to specific nature-oriented activities (birdwatching, nature study, etc.), it also includes informal recreation such as playing, walking, mountain biking, swimming, boating, and fishing	Liekens, et al., 2013 Book, 2018 EC, 2014 Boyto and Cooper, 2013 Blaksher and Lovasi, 2012 Mahdjoubi and Spencer, 2015 Taylor et al., 2008 Font and McCabe, 2017 Gregory-Smith et al., 2017
	Real estate prices	Research shows that nature and green spaces in the city have a positive effect on the value of real estate in the immediate vicinity. This reflects the fact that people value living close to a park, river, etc.	Aertsens, et al., 2012
	Education and raising awareness	Green environments allow us to experience nature, to enjoy and to learn about nature and the environment. For example, students can learn about the functioning of ecosystems. Moreover, the green infrastructure project can aid in raising awareness about current threats (air quality issues, rising sea level...), but also about good practices and potential solutions.	IALE, 2017 Reason, 2007 Natural England, 2009

Ecosystem services		Description and examples	References
Cultural	Social cohesion	Green infrastructure improves 'community cohesion' by strengthening the networks of (in)formal relationships among neighbourhood residents that foster a nurturing and mutually supportive human environment For example, parks and recreation areas are important meeting places for habitants (children, older people, etc.). Furthermore, if GI projects include citizens in the development of the project, these social ties will become even more important	CNT, 2011 Berger-Schmitt, 2002 Kearns and Forrect, 2000 Council of Europe, 2001 Cheong et al., 2007 Jenson, 2010 Zetter et al., 2006
	Attractor for companies and investments	This ES refers to the fact that green environments result in an attractive settlement for companies and employees to establish themselves in a specific region. In addition, several studies indicate that green space improves physical and mental health, reducing absenteeism and increasing productivity and motivation (Aertsens, et al., 2012). Furthermore, given that green areas attract people for leisure and recreation purposes, surrounding businesses might experience an increase in revenues.	Scottish Government, 2017 Liverpool City Region, 2020 Invest Glasgow, 2021

2.4. Step 2 – Parameter selection

2.4.1. Purpose of this step

This step gathers important information to estimate the costs and benefits for each scenario you described. Based on the selected ecosystem services (step 1), a table will appear where you will need to fill in some more specific data/parameters. This step will allow the tool to consider specific characteristics related to the project area during the calculations. Thus, the more precise information the user provides, the more accurate the calculations will be.

The basis for each of the calculations is provided in section 3.

2.4.2. Navigating the Excel tool

Based on the ES selected in the previous step, a table will appear with those same ES as well as some specific questions. Table 3 demonstrates all additional parameters that will be required for each ES.

Table 3: *Information requirement for each ES*

Ecosystem services		Parameters needed
Provisioning	Food	– No additional info needed
	Materials	– Will the planted trees be used to harvest wood in the future? – Projected time before harvesting trees: 10, 20, 30 or 40 years
Regulating	Carbon sequestration	– No additional info needed
	Micro-climate regulation (global climate regulation)	– Number of houses in close proximity (100m radius) of project area – Average price of electricity (€/kWh) – Average yearly electricity consumption per family in your region (in kWh) – Are you interested to calculate the indoor air temperature change caused by the green wall/green roof? – How many houses/buildings are directly covered by a green wall/green roof?
	Noise pollution	– Please estimate the current noise level based on the following categories: (1) Quiet Suburban residential area (< 55 dB); (2) Suburban residential area (55-59 dB); (3) Urban residential (60-64 dB); (4) Noisy urban residential area (65-69 dB); and (5) Very noisy urban residential area (> 70 dB) – Number of residents living in or around the project (max 100m radius)
	Water retention and infiltration	– Average precipitation per year in m^3/m^2 – Do you intend to collect water from outside of the project area (e.g. surrounding roofs)? – If you answered 'yes' to the previous question, how large is the surface area of the roofs/streets that you will collect water from? (m^2)
	Air filtering	– No additional info needed
Supporting	Habitat for biodiversity	– See worksheet 'C-Biodiversity' for biodiversity assessment (worksheet B-Biodiversity will be filled in for you)
Cultural	Aesthetic appreciation	– Number of residents living in or around (max 100m radius) the project area
	Physical and mental health	– Number of inhabitants within a 1000m radius?
	Recreation, and Tourism by external visitors	– The project area has the intention to promote tourism – Number of overnight stays booked by tourists in the city/region per year – The goal of the project area was/is recreation – The project area provides or will provide recreational facilities for people in the neighbourhood – Do you know the yearly number of visits today? (If yes, please fill in, if no use proxy's below) – Estimate the number of people living in a 300m radius – Estimate the number of people living in a 600m radius – Estimate the number of people living in a 1200m radius

Ecosystem services		Parameters needed
Cultural	Real estate prices	– Average housing prices in the area? – # houses extra to be overlooking water? – # houses extra to be overlooking open green space? – # houses extra to be overlooking a park? – # houses extra to be overlooking a forest? – # houses extra with/overlooking a green wall? – # houses extra in a street with trees?

In addition, since not all cultural benefits can be quantified and/or monetized, some qualitative statements will be offered which you will need to weight according to their significance for your municipality (for example, if they are corporate priorities or funders' requirements) and then score against each of your scenarios. This assessment takes place in worksheet D – Cultural ecosystem services and is explained in 2.4.6 below.

If you selected the ecosystem service 'water retention and infiltration' in step 1, one additional worksheet (A – Water retention) will appear to allow for the calculation of the avoided runoff. This tab does not require any information from the user. Similarly, if you selected the ecosystem service 'habitat for biodiversity' in step 1, two additional tabs (worksheets B - Biodiversity and C - Biodiversity) will appear to allow for a qualitative assessment. Worksheet Biodiversity - C does require some additional information from the user.

2.4.3. A – Water retention

2.4.3.1. Purpose of this step

This step will only appear if you had selected the ecosystem service 'water retention and infiltration' in worksheet S1 (selection). Based on the different scenarios and infrastructural types you defined in worksheet S0, this worksheet will calculate the water retention and infiltration capacity for different scenarios.

You may notice that the landscape elements you defined are not described identically here. That's because the worksheet groups those with identical retention capabilities together.

2.4.4. B – Biodiversity

2.4.4.1. Purpose of this step

This step will only appear if you had selected the ecosystem service 'habitat for biodiversity'. This ecosystem service is challenging to quantify, so we use two methods (see: worksheets B – biodiversity and C - biodiversity in the tool) to determine the impact of different scenarios on this ecosystem service. The first method focusses on the 'structural variation in infrastructure' (based on the amount of grey, green, and blue infrastructure).

In worksheet B – Biodiversity, '*The average structural diversity*' method or 'Shannon-Weaver index' is not used to calculate species diversity, but structural diversity. The more diversity in vegetation structure, the higher probability of more biodiversity. More specific, Shannon's index accounts for both abundance and evenness of the species present. The higher the index, the more diversity.

H' measures the diversity expected from the scenario, while H(max) is the maximum possible index which is achieved in this scenario if every land use layer is equally common. The 'effective number of species (D)', which is a diversity index, refers to the number of distinct layers, with a score between 1 and the number of layers present in a scenario. The higher this number, the greater the likelihood of that an increased number of species will (eventually) be present.

2.4.5. C – Biodiversity

2.4.5.1. Purpose of this step

The second method, 'potential habitat for target species', is based on the natural elements that different species need to survive in a landscape. The presence of those natural elements determines whether a species is likely to appear in the greened area or not. The more beneficial natural elements present for the species of interest, the more likely the green area will be a potential habitat for this species.

2.4.6. D – Cultural Ecosystem services

Depending on the cultural ES chosen in Step 1, a series of questions will appear in worksheet D – Cultural ecosystem services (Table 4). Each of these needs to be weighted according to its importance, on a scale of 1 to 5, and then scored for each scenario on a scale of 0 to 3. This allows a combined assessment of relative importance and effectiveness of delivery.

The questions are derived from academic literature and expert consultation on each of these issues; the framework was developed in collaboration with colleagues from Imperial College, London.

Table 4: *Cultural ES statements*

Ecosystem services		Statements
Cultural	Aesthetic appreciation	Does this scenario provide an aesthetically attractive place to live or work in? Do people value the area for its contribution to the local landscape or streetscape? Does this scenario make outdoor activities more enjoyable? Does this scenario include an attractive mix of different landscape elements? Does this scenario promote people's engagement with the natural world? Does this scenario create, or add to, a sense of place and visual identity? Do people enjoy spending time in and around this scenario area? Does this scenario contribute towards civic pride in the locality?
	Physical and mental health	Does this scenario provide an environment that help people relax and reduce stress? Does this scenario provide opportunities for people to socialise with neighbours? Does this scenario provide opportunities for volunteering and 'giving back'? Does this scenario encourage active outdoor exercise? Does this scenario reduce ambient noise, promote peace, quiet and tranquillity, and so contribute to people's mental health? Does this scenario provide space for sport and active play? Does this scenario provide green elements in a densely urban area? Does this scenario improve shading in the area to improve thermal comfort?

Ecosystem services		Statements
Cultural	Recreation and tourism by external visitors	Does this scenario provide a variety of opportunities for informal sport, play, and other physical activity? Does this scenario provide access to green space for local people? Does this scenario provide play and recreation opportunities for children and young people? Does this scenario promote participation in active physical exercise, for example walking, running, and other sports? Does this scenario promote equality of opportunity in play and recreation regardless of gender, ability/disability, and economic status? Does this scenario promote rest and relaxation? Does this scenario encourage people to spend more time outdoors? Does this scenario improve the attraction of the area to non-local visitors? Does this scenario provide space for events such as festivals, fairs, and entertainments? Does this scenario promote additional employment in jobs supporting tourism and visitors? Does this scenario increase the likelihood of the area to be featured in local tourist guides to the city/region? Does this scenario enhance the environmental setting of a heritage or cultural asset? Does this scenario offer a range of attractions to visitors? Does this scenario have sustainable transport links to other areas popular with visitors? Does this scenario promote responsible, sustainable and universally accessible tourism, addressing the 2030 Sustainable Development Goals?
	Education and awareness	Does this scenario include interpretation to help people understand its value? Does this scenario provide opportunities for engagement with nature? Does this scenario enhance people’s understanding of ecology and landscape? Does this scenario provide opportunities to attract visits from schools and from other groups wanting to understand its value? Does this scenario raise awareness of climate change and actions to mitigate its effects? Does this scenario serve as an example that might inspire other municipalities? Does this scenario improve opportunities to volunteer and develop skills and capabilities?

Ecosystem services		Statements
Cultural	Social cohesion	Does this scenario encourage people to spend more time in the public realm?
		Does this scenario offer opportunities for local people to meet and socialise, e.g. providing benches, spaces for picnics?
		Does this scenario increase opportunities to participate in community activities?
		Does this scenario provide space for activities and events to take place?
		Does this scenario make local residents likely to feel more happy/proud to live in the locality and therefore less likely to move away?
		Does this scenario help to reduce anti-social behaviour?
		Does this scenario contribute to a sense of place and visual identity?
		Does this scenario support people, and/or groups of people, who are socially or economically marginalised?
		Does this scenario increase volunteering and informal support within the local community?
	Attracting companies and investments	Does this scenario improve the appeal of the area to businesses and encourage them to set up or relocate in this locality?
		Does this scenario improve the appeal of the area to potential customers for businesses operating in this area?
		Does this scenario provide an attractive environment for employees to work in?
		Does this scenario enhance the infrastructure that businesses need to operate more economically?
		Does this scenario allow local businesses to adopt greener ways of working, to associate themselves with green ideas, or to deliver against environmental commitments?
		Does this scenario increase business resilience and reduce the risk of climate-related loss or damage to businesses operating in the area?
		Does this scenario reduce the carbon footprint of business, and/or mitigate any environmental damage created by business activity?

2.5. Step 3 – Quantification and Step 4 – Qualification

2.5.1. Purpose of these steps

These are results pages that sets out the impact each scenario has on the selected ecosystem services. Step 3 shows the results of the calculations for those ES that can be addressed in this way, while Step 4 sets the results from Step 3 alongside the results of the calculation carried out on cultural ES in worksheet D – Cultural ecosystem services. The results are translated into simple scores that are plotted on to a spider diagram to provide a visual representation of the comparison between scenarios. The user can overwrite the scores being generated here, and will need to do so for the results carried forward from Step 3.

2.6. Step 5 – Monetization

In this fifth step, the LA should make an estimation of the project construction or capital costs as well as the maintenance costs for each scenario or use the generic data provided. The MCA tool will convert the previously calculated biophysical values into monetary terms to allow a financial appraisal of the benefits being secured.

2.6.1. Costs

2.6.1.1. Purpose of this step

In order to estimate the financial performance of each scenario, the MCA tool requires a precise overview of the construction and maintenance costs for each scenario. These costs can vary widely depending on the size of the project and the materials that are used, but they are generally more accessible than the (biophysical) values of ES.

If the GI project has been discussed with a contractor, the contractor will be able to provide an estimation of the project costs. It may also be possible to use costs from a similar, earlier project. But if there are no suitable cost data available, the tool provides a set of typical costs which can be used. And where more detailed info is available, these typical costs can be overridden by the user.

2.6.2. Benefits

Besides estimating the costs for each scenario, this step also requires estimating the economic or monetary value of the selected ES. There are three general types of economic valuation methods, each with its own repertoire of associated measurement methods:

- the direct market valuation
- the indirect market valuation
- the non-market valuation

The **direct market valuation methods** probe for the exchange value that ES have in trade. This method can be applied to ‘goods’ such as the production functions, as well as some cultural (e.g. recreation) and regulating ES (de Groot, Wilson, & Boumans, 2002).

The second group of methods are the **indirect market valuation methods or revealed preference methods**, which are used in situations where there are no explicit markets for that service. By, indirectly asking for respondents (revealed) Willingness To Pay (WTP) or Willingness To Accept compensation (WTA), the value of ES can be estimated. In other words, the value of ES can be based on the observed behaviour of people in related markets. Techniques include: the avoided or replacement costs, factor income, hedonic pricing, travel cost method, etc. (Cordier, Agúndez, Hecq, & Hamaide, 2014).

The **non-market valuation methods** rely on the stated preference of respondents. These techniques or methods do not require a concrete connection between values and money, but still provide information about relative values, rankings, or equivalencies (Farber, et al., 2006). Techniques that are often used include the contingent valuation method and the choice experiment (Koetse, Brouwer, & Van Beukering, 2015).

There are also other categorisations of economic valuation methods possible. For instance, de Groot et al. (2002) would use four categories: the direct market valuation, the indirect market valuation, the contingent valuation, and the group valuation methods. Turner et al. (2016) would rely on two categories of methods, the revealed and stated preference methods.

Some scholars such as de Groot et al. (2002) are convinced that the monetary value of ES can be calculated or estimated with one or more known techniques. Yet, other scholars such as Fisher et al. (2009) and Turner et al. (2004) strongly believe that not all ES can be monetized. According to those scholars, the supporting and regulating ES cannot be covered by economic valuation techniques, since they are assumed to be independent of individual preferences. Yet, monetary valuation methods and techniques are still used to monetize the value of the supporting and regulating ES (Cordier, Agúndez, Hecq, & Hamaide, 2014). The MCA also encourages to value and monetize all ES that are relevant for a specific case but also recognizes the challenges and critiques regarding those techniques.

2.6.3. Navigating the Excel tool

The MCA tool relies on different methods (see table 5) to monetize the ES without expecting extensive information and efforts from the user. Moreover, the tool allows for the user to change the social discount rate. This table summarises the calculations, but readers seeking more detailed information should consult the next section.

Table 5: *Monetization summary*

Ecosystem services		Reasoning and methods
Provisioning	Food	To monetize this ES the tool uses the information about the average production (which was calculated in step 3 qualification) and the market value of fruits and vegetables (January 2020).
	Materials	To monetize this ES the tool uses the information about the average wood production (which was calculated in step 3 qualification) and the market value of wood.
Regulating	Carbon sequestration	To monetize this ES the tool uses the information about the average carbon sequestration (which was calculated in step 3 qualification) and the market value of wood.
	Micro-climate regulation (global climate regulation)	To monetize this ES the tool uses the information about the average temperature reduction (which was calculated in step 3 qualification), the number of houses in the targeted area, and the average price of electricity (requested in step 2, parameter selection). With this information the tool will calculate two things: the avoided cost of electricity for cooling (within a household) and the value of 'thermal comfort'.
	Noise pollution	To monetize this ES the tool uses the information about the average dB reduction (which was calculated in step 3 qualification), the initial noise level (requested in step 2, parameter selection), and the willingness-to-pay of people in the region to reduce the noise pollution. With this information the tool will calculate the willingness-to-pay of people for a noise reduction.
	Water retention and infiltration	To monetize this ES the tool uses the information about the avoided runoff (which was calculated in step 3 qualification) and the cost of processing runoff water through the sewage system. With this information the tool will calculate the avoided cost of sewage.

Ecosystem services		Reasoning and methods
Cultural	Aesthetic appreciation	The value of this ES varies depending on the statements categorized as ‘correct’ in step 2 (parameter selection).
	Physical and mental health	The value of this ES is based on DALY, where one DALY represents the loss of the equivalent of one year of full health.
	Recreation, and Tourism by external visitors	This ES is valued based on two parameters: the average number of visitors to a certain area (this depends on the population density) and the number of overnight stays booked by tourists.
	Real estate prices	This ES is valued based on the average house prices in the region and the number of houses in proximity of different types of green infrastructure, this information is requested in step 2 (parameter selection).

Please remember that not all ES are monetized. Therefore, the actual benefits will very likely be higher than estimated.

3. Quantification and monetization

This section provides more detail on how the calculations within the Business Model are done, and sources that have been employed in constructing the method.

The calculations being made for each ecosystem service are set out here:

3.1. Food

Introduction

This ES refers to the quantity of crops and fruits that are harvested within a certain area (Liekens, et al., 2013). For instance, by implementing allotment gardens or planting fruit trees, residents can benefit from the food that is produced. The provisioning ES of food comes to practice in urbanized environments in the form of urban agriculture (UA) and edible green infrastructure (EGI). UA and EGI include various ways of food production including allotment gardens, community gardens, container gardens, edible green roofs, floating farms, private gardens, hydroponic systems, rooftop gardens, etc. (Aerts, Dewaelheyns, & M.J. Achten, 2016; Russo, Escobedo, Cirella, & Zerbe, 2017). UA can produce fruits, vegetable crops, aromatic spices, eggs, and poultry. Although UA in developed or industrialized countries only makes a limited contribution to improving food self-sufficiency (Clarke, Li, Jenerette, & Yu, 2014; Lynch, Maconachie, Binns, Tengbe , & Bangura, 2013), yet, more and more households are engaging in UA (Mok, et al., 2014).

To value or monetize the food provided by this ES, some information is required: (1) amount of food produced (in kg/tree or kg/m^2) and (2) the market prices consumers pay for vegetables, fruit, and herbs in the supermarket, this can vary depending on the region and season. Furthermore, it is important to mention that these calculations are often based on the assumption that 100% of the harvested fruits, vegetables, herbs, eggs, etc. will be consumed. This method is also not reflecting yearly fluctuations in expected harvest because of meteorological or other circumstances. Moreover, plant productivity may vary over different subspecies.

Quantification

To quantify this ES, 12 of the most common fruits and vegetables in Europe were integrated in the BM. For each of these 12 types of GI ballpark figures on the quantity of fruits and vegetables is produced per tree or per square meter on average (see table 6). For the apple, pear, cherry, and citrus trees, as well as the berry hedges and grapevines, a linear increase was assumed starting from year 0 (planting) up until a constant level of production when the respective fruit tree/bush reaches a state of maturity (max. food production). For the other vegetables and fruits categorized under 'allotment garden', we assumed a constant production. This method was based on Hendrix et al. (2015).

Table 6: *Food*

GI type	Unit	Food (kg/m^2/yr)		Source (mostly grey literature)
Fruit tree (apple)	amount	50	250 (kg/tree/yr)	https://www.vigopresses.co.uk/AdditionalDepartments/Header-Content/Make-apple-juice/Where-to-start-2
Fruit tree (pear)	amount	45	90 (kg/tree/yr)	https://wikifarmer.com/pear-tree-harvest-and-yield/
Fruit tree (cherry)	amount	27,5	48,5 (kg/tree/yr)	https://www.almanac.com/plant/cherries
Fruit tree (citrus)	amount	150	180 (kg/tree/yr)	https://www.daf.qld.gov.au/business-priorities/agriculture/plants/fruit-vegetable/fruit-vegetable-crops/citrus/harvesting,-yields-and-prices
Hedge (berries)	amount	2,5	3,5 (kg/bush/yr)	http://www.omafra.gov.on.ca/english/crops/facts/90-046.htm
Green façades (grapes)	m^2	6,8	15,9	https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/ec1639.pdf (assuming 1 vine per m^2)
Allotment garden (potatoes)	m^2	2	2	https://survlivel.cultu.be/how-many-m^2-4-self-sustainable
Allotment garden (onions and garlic)	m^2	2,5	2,5	https://vikaspedia.in/agriculture/crop-production/package-of-practices/vegetables-1/onion-allium-cepa#section11
Allotment garden (carrot and root vegetables)	m^2	7,5	7,5	https://wikifarmer.com/grow-carrots-summary/
Allotment garden (tomatoes)	m^2	6	6	https://www.freshplaza.com/article/9188879/tomato-yield-in-the-netherlands-is-6-times-greater-than-in-spain/
Allotment garden (lettuce and leaf vegetables)	m^2	3	3	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4483736/
Allotment garden (strawberry)	m^2	3,9	3,9	https://extension.psu.edu/strawberry-production (assuming 8 strawberry plants per m^2)

Monetization

The quantification step provided an overview of the yearly production (in kg) per square meter or per tree. Following the methodology used by Hendrix et al. (2015), the quantified results were converted to monetary values based on the market prices (in January 2021) in a Belgian supermarket (Hendrix, et al., 2015). Note that these prices are subject to fluctuations over time, hence why users are strongly advised to check these values with actual market prices.

3.2. Materials

Introduction

Vegetation is a source of biomass. Biomass refers to a variety of (plant) materials such as wood, trimmings, and other vegetable residues. These materials can be used to produce energy and other products such as benches and climbing racks (Aertsens, et al., 2012).

To value or monetize this ES, some information is required: (1) quantity of wood produced (in m^3/tree) and (2) the market prices for wood, this can vary depending on the region, season, and type of wood. Furthermore, it is important to mention that these calculations are based on the assumption that 100% of the materials are used.

Quantification

The quantification of this ES is based on categorisations of small ($14m^2$), medium ($37m^2$), and large ($84m^2$) trees that were deployed in the project description, bushes and hedges are not considered in the calculations. A small, medium, and large tree bring forth 0,25, 1, and 4 m^3 of wood respectively on average. Please note that is not a yearly benefit, since harvesting wood requires to cut down trees, leading to the end of its lifespan. If trees are used for materials, they are assumed not to contribute to generation of other ES, to avoid double counting.

Monetization

The quantification step calculates the total amount of cubic meters of wood that is produced. Following the method used by Hendrix et al. (2015) of the ES 'food', the quantified results were converted to monetary values based on the market price of firewood provided on the website of van Leersum (van Leersum, 2022). Note that this is a one-time benefit and that these prices might fluctuate over time.

3.3. Carbon Sequestration

Introduction

This ES refers to the quantity of carbon GI absorbs from the environment. Carbon sequestration refers to the process of capturing and storing atmospheric carbon dioxide (Nowak & Crane, 2002). More specific, plants convert carbon dioxide (CO_2) into biomass, this process is called photosynthesis. CO_2 is an important greenhouse gas that contributes to global warming and is released through the combustion of fossil fuels. The more atmospheric carbon is captured, the less it can contribute to global warming (Kuittinen, Moinel, & Adalgeirsdottir, 2016). In that sense, carbon sequestration contributes to global climate regulation.

Global climate regulation is an ES that stretches far beyond the local scale. The benefits of the service are global, in contrast to the benefits of other ES. Generally, the total carbon uptake will be small compared to the total CO_2 emissions due to the limited green space in most cities. Nevertheless, it is useful to value carbon storage in urban vegetation since the relative importance of carbon sequestration will increase over time as global warming becomes a bigger problem (Hendrix, et al., 2018). Moreover, an increasing number of municipalities are setting objectives to reduce their carbon footprint. Quantifying the effect of GI on carbon sequestration contributes to monitoring progress.

A study in 28 cities in the United States calculated the carbon storage and sequestration by urban trees. The results showed that an urban tree sequestrates on average 0.28kg of carbon per square meter of tree cover per year and has a carbon storage density of 7.69kg of carbon per square meter of tree cover. Furthermore, the study estimated that for 2005, the total tree carbon storage in U.S. urban areas at 643 million tonnes (with a value of $50.5 billion) and annual sequestration is estimated at 25.6 million tonnes (with a value of $2.0 billion) (Nowak, Greenfield, Hoehn, & Lapoint, 2013). Another study by Strohbach and Haase (2012) found that the carbon storage per square meter of tree cover varies between 0.68kg to 9.85kg in afforestation and forest areas in Leipzig, respectively. Concluding that the average carbon storage per square meter of tree cover is 6.82kg of carbon (Strohbach & Haase, 2012).

To calculate a biophysical value of this ES, one needs to gather data regarding the surface area per green infrastructure type. In cities, 97% of the carbon in biomass is contained in trees (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011). The thicker the trees, the more carbon uptake. However, CO_2 sequestration is not the only factor influencing the global climate. GI such as insulating green roofs can result in less CO_2 emissions for heating and cooling systems (Hendrix, et al., 2018). By using the avoided cost method, this ES can be translated into monetary terms. De Nocker et al. (2010) calculated key figures based on the cost of emission reduction measures needed to ensure that the global average temperature does not increase by more than 2°C compared to pre-industrial levels. They estimate that the marginal costs will increase over time, from €20/ton CO_2 in 2005, to €100/ton CO_2 in 2030, to €220/ton CO_2 in 2050.

Quantification

For this ES the BM relies on the evidence base provided by the IGNITION project. The IGNITION database provides an overview of how much carbon different (see table 7) types of green infrastructure can sequester per year (Greater Manchester Combined Authority, 2021).

Table 7: *Carbon sequestration*

Element	Type	Unit	Carbon sequestration (kg/m²/yr)
Green wall	Green façades	m²	0,68
	Living wall	m²	0,68
	Vegetated mats, felt systems, or modular	m²	0,68
	Hydroponic green walls	m²	0,68
	Hedges	m²	0,57
Trees and shrubs	Single tree (>12m)	amount	5,5 (kg/tree/yr)
	Single tree (6m-12m)	amount	5,5 (kg/tree/yr)
	Single tree (<6m)	amount	5,5 (kg/tree/yr)
	Broad-leaved woodland	m²	0,99
	Coniferous woodland	m²	0,99
	Mixed woodland	m²	0,99
	Herbaceous plants	m²	0,57
	Shrubby plants	m²	0,57
Fruit and vegetables	Fruit tree (apple)	amount	5,5 (kg/tree/yr)
	Fruit tree (pear)	amount	5,5 (kg/tree/yr)
	Fruit tree (cherry)	amount	5,5 (kg/tree/yr)
	Fruit tree (citrus)	amount	5,5 (kg/tree/yr)
	Hedge (berries)	amount	0,57 (kg/hedge/yr)
	Green façades (grapes)	m²	0,68
	Allotment garden (potatoes)	m²	0,2
	Allotment garden (onions and garlic)	m²	0,2
	Allotment garden (carrot and root vegetables)	m²	0,2
	Allotment garden (tomatoes)	m²	0,2
	Allotment garden (lettuce and leaf vegetables)	m²	0,2
	Allotment garden (strawberry)	m²	0,2

Element	Type	Unit	Carbon sequestration (kg/m²/yr)
Low green	Lawn	m²	0,2
	Amenity grassland	m²	0,2
	Tall grass	m²	0,2
	Flower field	m³	0,2
Green roof	Extensive green roof	m²	1,28
	Intensive green roof	m²	1,28
Sustainable drainage systems	Rainwater harvesting	m²	0,183
	Filter drain or infiltration trench	m²	0,27
	Filter (buffer) strips or swales	m²	0,27
	Wetlands, ponds or retention areas	m²	0,183
	Soakaways	m²	0
	Bioretention areas	m²	0,183
	Trench-troughs or wadis	m²	0
	Flowing water	m²	0
(Semi-)permeable surface	Semi-permeable grow-through pavers	m²	0,1
	Permeable stone/pavement	m²	0,1
	Wood chips or bark	m²	0
	Loose surfaces	m²	0
	Natural playground	amount	0
	Rustic playground	amount	0
Overgrown	Overgrown	m²	0,4
Grey infrastructure	Impermeable surface	m²	0
	Storm sewage	m³	0
	Brick wall	m²	0
	Normal roof	m²	0
	Concrete pond/lake	m²	0
	Traditional playground	m²	0

Source: *(Greater Manchester Combined Authority, 2021)*

Monetization

Based on the quantified results this ES can be monetized following the methodology used by Hendrix et al. (2015). First, the carbon sequestration values are multiplied with 3.67 to calculate the equivalent amount of CO_2 that is captured this way. We then use the data provided in the manual of the GI-Val tool by the Ecosystems Knowledge Network (2021) and assume that the price of carbon is subject to a linear increase of €67,5/tonne of carbon dioxide in 2020 up to €225/tonne of carbon dioxide in 2050 (The Mersey Forest, Natural Economy Northwest, CABE, Natural England, Yorkshire Forward, The Northern Way, Design for London, Defra, Tees Valley Unlimited, Pleasington Consulting Ltd, and Genecon LLP (2010), 2018).

3.4. Micro-climate regulation

Introduction

Phelan et al., (2015; p.286) defined the urban heat-island effect as the "difference in temperature between the built environment and the natural (surrounding) environment". Generally, urban areas are warmer than rural areas. One of the main drivers of this urban heat-island effect is the modifying land cover (Marando, Salvatori, Sebastiani, Fusaro, & Manes, 2019). Cities, characteristics ensure a higher temperature during the day, evening and at night. Grey infrastructure or man-made materials absorb and store solar energy during the day and release it back during the day and at night (Phelan, et al., 2015). According to Phelan et al., (2015) the urban heat-island effect in cities around the world ranges from 4°C in Athens and Sidney, up to 12°C in Tokyo. A study conducted in Rome, during spring and summer, found that the temperatures in the city were on average 1°C higher during the day and between 1.85°C and 2.15°C higher at night, in comparison with rural areas. Furthermore, the study found that (peri-)urban forests were between 2.5–3.2°C cooler than their surroundings and that the cooling effect could extend up to 170m around the (peri-)urban forest (Marando, Salvatori, Sebastiani, Fusaro, & Manes, 2019). According to Zhang et al. (2017), significant cooling potentials of approximately 1–2°C locally and 0.5°C regionally can be achieved by implementing green space in cities. The study also demonstrates that clustered green space enhances local cooling because of the agglomeration effect, whereas dispersed patterns lead to greater overall regional cooling.

This cooling effect is important since heat negatively influences human health. After all, the ambient temperature is one of the most important factors influencing sleep. For instance, a study in the U.S. found a correlation between atypical nightly temperatures and insufficient sleep (Obradovich, Migliorini, Mednick, & Fowler, 2017). Furthermore, figures show that there are more hospital admissions during heat waves (Gronlund, Zanobetti, Schwartz, Wellenius, & O'Neill, 2014; Wang, et al., 2012). Prolonged heat waves can lead to heat-related illnesses such as cramps, fainting, and strokes. In extreme cases, this leads to an increase in mortality (Hendrix, et al., 2018). By means of an example, the temperature during the hot European summer of 2003, were responsible for more than 70,000 additional deaths in Europe (Robine, et al., 2008). Furthermore, the WHO estimates 250,000 annual deaths due to the urban heat-island effect between 2030 and 2050 if no adaptation actions are taken (WHO, 2014).

Green roofs and green facades have an additional positive effect on a building's energy needs, especially when it uses an air-conditioning system during the summer. Green roofs will also provide extra insulation during the winter, which will reduce energy demand. However, a green roof requires an investment (the cost price is about twice as high as for a normal roof), but research shows that a green roof lasts longer because it is less prone to extreme temperatures (Hendrix, et al., 2018). Furthermore, water features in cities also have a cooling effect (Coutts, Tapper, Beringer, Loughnan, & Demuzere, 2012). The easier the water can evaporate, the greater the cooling effect. A spraying fountain, for example, will provide more cooling than stagnant water (Nishimura, Nomura, Iyota, & Kimoto, 1998).

Quantification

This ES can be subdivided into two sperate categories: micro-climate regulation outdoor and indoor. The *outdoor micro-climate regulation* quantification is based on a methodology used by Ziter et al. (2019). For the BM the methodology was simplified since the BM does not include information about how the infrastructure is distributed. The first step was to research the average cooling-effect for every type of GI by using the IGNITION database (Greater Manchester Combined Authority, 2021) and the 'Groentool Antwerpen' (Groentool Antwerpen, 2021) (see table 8 for an overview). The BM assumes that within a specific scenario, the green elements selected in S0 are equally distributed over the whole project area. Ziter et al. (2019) method requires to create as many circles of 30m diameter as necessary to cover the whole project area and within these circles, the impervious and canopy cover compared). Knowing the total project area, the different types of GI, the surface area of green and grey infrastructure, and the average effect on ambient temperature of each type of GI, the weighted average of temperature decrease is calculated (Ziter, Pedersen, Kucharik, & Turner, 2019). Please note that there are many other factors influencing temperature that were not taken into account (e.g. wind, daily temperature, location of the project area, etc.).

The *indoor micro-climate regulation* quantification is also loosely based on the methodology used by Ziter et al. (2019) and follows the same principles as the calculations above. However, only green walls and green roofs are considered when calculating the indoor temperature decrease, other types of GI are not considered (see table 8), to avoid double counting. Again, it is assumed that the green roof/wall is equally distributed over the building(s). With this information, the weighted average of temperature decrease indoor is calculated. Please note that the BM calculates the temperature decrease for the rooms immediately below the green roof or next to the green wall. Moreover, the effect might be larger/smaller depending on the insulating material, other GI in the immediate vicinity, the temperature of a specific day, etc.

Table 8: *Micro-climate regulation*

Element	Type	Unit	Micro-climate regulation (C° reduction in surrounding temperature)	Micro-climate regulation (C° reduction in indoor temperature)
Green wall	Green façades	m²	1,5	2,7
	Living wall	m²	2,3	4,8
	Vegetated mats, felt systems, or modular	m²	2,3	4,8
	Hydroponic green walls	m²	2,3	4,8
	Hedges	m²	0,25	0
Trees and shrubs	Single tree (>12m)	amount	3	0
	Single tree (6m-12m)	amount	3	0
	Single tree (<6m)	amount	3	0
	Broad-leaved woodland	m²	2	0
	Coniferous woodland	m²	2	0
	Mixed woodland	m²	2	0
	Herbaceous plants	m²	0,5	0
	Shrubby plants	m²	0,5	0
Fruit and vegetables	Fruit tree (apple)	amount	3	0
	Fruit tree (pear)	amount	3	0
	Fruit tree (cherry)	amount	3	0
	Fruit tree (citrus)	amount	3	0
	Hedge (berries)	amount	0,5	0
	Green façades (grapes)	m²	1,5	0
	Allotment garden (potatoes)	m²	2,5	0
	Allotment garden (onions and garlic)	m²	2,5	0
	Allotment garden (carrot and root vegetables)	m²	2,5	0
	Allotment garden (tomatoes)	m²	2,5	0
	Allotment garden (lettuce and leaf vegetables)	m²	2,5	0
	Allotment garden (strawberry)	m²	2,5	0

Element	Type	Unit	Micro-climate regulation (C° reduction in surrounding temperature)	Micro-climate regulation (C° reduction in indoor temperature)
Low green	Lawn	m^2	2,5	0
	Amenity grassland	m^2	2,5	0
	Tall grass	m^2	2,5	0
	Flower field	m^3	2,5	0
Green roof	Extensive green roof	m^2	0	3
	Intensive green roof	m^2	0	2,02
Sustainable drainage systems	Rainwater harvesting	m^2	1	0
	Filter drain or infiltration trench	m^2	1	0
	Filter (buffer) strips or swales	m^2	1	0
	Wetlands, ponds or retention areas	m^2	1	0
	Soakaways	m^2	1	0
	Bioretention areas	m^2	1	0
	Trench-troughs or wadis	m^2	1	0
	Flowing water	m^2	1	0
(Semi-)permeable surface	Semi-permeable grow-through pavers	m^2	1,25	0
	Permeable stone/pavement	m^2	1,25	0
	Wood chips or bark	m^2	0,5	0
	Loose surfaces	m^2	0,5	0
	Natural playground	amount	0	0
	Rustic playground	amount	0	0
Overgrown	Overgrown	m^2	0,5	0
Grey infrastructure	Impermeable surface	m^2	0	0
	Storm sewage	m^3	0	0
	Brick wall	m^2	0	0
	Normal roof	m^2	0	0
	Concrete pond/lake	m^2	0	0
	Traditional playground	m^2	0	0

Source: *(Greater Manchester Combined Authority, 2021; Groentool Antwerpen, 2021)*

Monetization

To monetize the *outdoor micro-climate regulation* the BM relies on 2 methods: (1) the avoided cost of electricity (cooling) for households in and/or in the direct vicinity of the project area (Alves, Gersonius, Zoran, Vojinovic, & Sanchez, 2019) and (2) the willingness-to-pay for thermal comfort and health (CRC for Water Sensitive Cities, 2016).

Alves et al. (2019) found that households can save on average 3% in energy consumption for each degree (°C) of temperature reduction due to pervious pavements installation in direct proximity of those houses (Alves, Gersonius, Zoran, Vojinovic, & Sanchez, 2019). A linear relation between the impact on energy consumption and temperature reduction was assumed. Knowing how many houses are in the project area or in direct proximity, the average energy consumption of households, and the average price per kWh, the BM calculates the average annual energy savings. We combined this method with stated preference experiment in Melbourne and Sydney. This experiment revealed that there is significant economic support for projects that reduce summer temperatures. More specific, households are prepared to pay between A$47 (€30) and A$81 (€51) per household per year for a 2C° reduction. Based on these results, the BM assumes that for every 2°C reduction, households are willing to pay on average €40,5 (Brent, Gangadharan, Leroux, & Rashcy, 2016; CRC for Water Sensitive Cities, 2016). These monetary impacts were assumed to be linear.

To value *indoor micro-climate regulation* the BM relies on the findings of Alves et al. (2019) mentioned above.

Please note that there are also other benefits such as the avoided cost of preliminary deaths among elderly people and the impact of heat on the degradation of urban infrastructure (e.g. distorted train track), that are not considered in the BM. Valuing/monetizing these effects would contribute to the risk of double counting, since other ES adopted in the model (mental and physical health) account for these events as well.

3.5. Noise pollution

Introduction

This ES refers to the capacity of vegetation to reduce noise levels (from traffic and other sources) (Liekens, et al., 2013). Noise pollution or elevated sound levels have physical and psychological effects on humans. Noise is a known stressor that affects the autonomic nervous system and the endocrine system. Since urbanization is predicted to keep rising in the future, it will lead to more traffic and a fast-growing industry resulting in a considerable increase in noise and air pollution (Geravandi, et al., 2015). A literature study by Geravandi et al. (2015) found that noise pollution is associated with many health issues including myocardial infarction, hypertension, cardiovascular disease, limited sleep quality, mental disorders, and immune system. Transportation (vehicles, airplanes, and public transportation systems) is the main source of noise pollution in cities (Mirzaei, Ansari-Mogaddam, Mohammadi, Rakhsha, & Salmanpor, 2012).

At the beginning of this century, 210 million people of the EU25 (about 44%) were regularly exposed to about 55 decibels of road traffic noise. Moreover, 35 million people in the EU25 (about 7%) were regularly exposed to noise above 55 decibels. These levels of noise are potentially dangerous to human health. Meaning that millions of people are, or will be, experiencing negative health effects due to noise pollution. It is estimated that the social cost of traffic noise alone will amount to at least 40 billion per year for EU22 (0.4% of total GDP) (den Boer & Schroten, 2007). Another study by Margaritis and Kang (2017) in 25 European cities found less noise pollution in the cities with a higher extent of porosity and green space coverage (when measured at the urban level). In addition, a study in Bulgaria found that interaction with or proximity to green spaces have a beneficial impact on noise perception, although the mechanisms underlying these effects require further research (Dzhambova & Dimitrova, 2015).

Quantification

The quantification of this ES is based on information gathered in the IGNITION database (Greater Manchester Combined Authority, 2021) and the 'Groentool Antwerpen' (Groentool Antwerpen, 2021). For each type of GI it is determined to which extent noise pollution is mitigated (see table 9 for an overview). The BM assumes that within a specific scenario, the green elements selected in S0 are equally distributed over the whole project area. Hence, effects of multiple, combined and mutually reinforcing green barriers are not considered. Knowing the total project area, the different types of GI, the surface area of GI, and the average dB reduction by each type of GI, the weighted average noise reduction is calculated. Please note that there are many other factors influencing noise reduction that were not taken into account (e.g. wind, location of the project area, type of noise, etc.). Moreover, this benefit strictly applies to residents in the direct vicinity of the respective green elements, a sensitivity that would require location specific valuation to be more accurate. Our results should thus be interpreted as aggregate estimations.

Table 9: *Noise reduction*

Element	Type	Unit	Noise pollution (dB reduction)
Green wall	Green façades	m^2	2,6
	Living wall	m^2	9,75
	Vegetated mats, felt systems, or modular	m^2	9,75
	Hydroponic green walls	m^2	9,75
	Hedges	m^2	4
Trees and shrubs	Single tree (>12m)	amount	6
	Single tree (6m-12m)	amount	6
	Single tree (<6m)	amount	6
	Broad-leaved woodland	m^2	7,5
	Coniferous woodland	m^2	7,5
	Mixed woodland	m^2	7,5
	Herbaceous plants	m^2	2
	Shrubby plants	m^2	2
Fruit and vegetables	Fruit tree (apple)	amount	6
	Fruit tree (pear)	amount	6
	Fruit tree (cherry)	amount	6
	Fruit tree (citrus)	amount	6
	Hedge (berries)	amount	2
	Green façades (grapes)	m^2	2,6
	Allotment garden (potatoes)	m^2	4
	Allotment garden (onions and garlic)	m^2	4
	Allotment garden (carrot and root vegetables)	m^2	4
	Allotment garden (tomatoes)	m^2	4
	Allotment garden (lettuce and leaf vegetables)	m^2	4
	Allotment garden (strawberry)	m^2	4

Element	Type	Unit	Noise pollution (dB reduction)
Low green	Lawn	m^2	4
	Amenity grassland	m^2	4
	Tall grass	m^2	4
	Flower field	m^3	4
Green roof	Extensive green roof	m^2	0
	Intensive green roof	m^2	0
Sustainable drainage systems	Rainwater harvesting	m^2	0
	Filter drain or infiltration trench	m^2	0
	Filter (buffer) strips or swales	m^2	0
	Wetlands, ponds or retention areas	m^2	0
	Soakaways	m^2	0
	Bioretention areas	m^2	0
	Trench-troughs or wadis	m^2	0
	Flowing water	m^2	0
(Semi-)permeable surface	Semi-permeable grow-through pavers	m^2	1
	Permeable stone/pavement	m^2	1
	Wood chips or bark	m^2	2
	Loose surfaces	m^2	2
	Natural playground	amount	1
	Rustic playground	amount	1
Grey infrastructure	Impermeable surface	m^2	0
	Storm sewage	m^3	0
	Brick wall	m^2	0
	Normal roof	m^2	0
	Concrete pond/lake	m^2	0
	Traditional playground	m^2	0

Source: *(Greater Manchester Combined Authority, 2021; Groentool Antwerpen, 2021)*

Monetization

The monetization of this ES is based on research by Bjørner (2004) who found that people are willing to pay between €2 and €10 for a one dB noise reduction, depending on the initial noise level (Bjørner, 2004). This effect was assumed to be linear. Since this study is from 2004, the numbers have been adjusted to the current price levels. Moreover, the initial noise levels have been classified following the categorization proposed by the Federal Aviation Administration, from 'quiet suburban area' tot 'very noisy urban residential area' (Federal Aviation Administration, 2018). With information about the initial noise level, the expected dB reduction, and the number of people living in/around the project area, the BM can monetize this ES (see table 10). Middle-point values were than used to appoint a WTP estimation to a certain baseline noise level.

Table 10: *Noise monetization*

Initial noise level	< 55dB Quiet Suburban residential area	55 - 59dB Suburban residential area	60 - 64dB Urban residential	65 - 69dB Noisy urban residential area	> 70dB Very noisy urban residential area
WTP/ person/ year/db	€2,50	€5,20	€7,75	€10,30	€13,00

Source: *Bjørner, 2004; Federal Aviation Administration, 2018*

3.6. Water retention

Introduction

Rapid urbanization, climate change, and inappropriate urban planning policies have resulted in urban water-related problems (e.g., flooding disasters, water pollution, and water shortages) in many urbanized environments. Specifically, the over-use of grey infrastructure, creating impermeable surfaces, makes it even more challenging to manage the rain and ground water. The less natural rainwater-retaining infrastructure (e.g., green spaces, natural lakes, and wetlands), the higher the probability of flooding and low levels of ground water. Furthermore, impermeable surfaces hinder the natural rainwater recycling processes where stormwater is discharged as wastewater (leading to higher water volumes in sewage systems) rather than being absorbed into the soil (Nguyen, et al., 2019).

Generally, cities with 50–90% impervious cover can lose 40–83% of rainwater to surface runoff (Bonan, 2016). More GI in urban areas reduces surface runoff by increasing water infiltration opportunities locally. According to Hendrix et al. (2018) green roofs retain between 58-81% of the rainwater; rivers and lakes retain 100% of the rainwater; (flower) gardens and meadows retain between 72-100% of the rainwater; forests, city trees, and allotment gardens retain between 50-100% of rainwater (ICLEI, 2006). In other words, by facilitating water absorption, GI reduces the pressure on urban drainage systems.

Quantification

For this ES we gathered the retention coefficient for different types of GI from the Flemish Nature Value Explorer tool (Hendrix, et al., 2018) and from Flemish research (Verbeeck, Van Rompuy, Hermy, & Van Orshoven, 2013) (see table 11). The retention coefficient denotes the percentage of runoff that will be retained by GI. By combining the average yearly rainfall, the surface area of different GI types, and the retention coefficients, the BM can calculate the quantity yearly retained runoff.

Table 11: *Water retention*

Green/blue elements	Retention coefficient
Lawn & Amenity grassland	0,72
Overgrown	1,00
Tall grass	1,00
Flower Field	1,00
Middle green	0,78
Trees	0,51
Woodland	1,00
Water elements	1,00
Semi-permeable	0,70
Impermeable	0,02
Green wall	0,18
Allotment gardens	0,90

Source: *(Hendrix, et al., 2018; Verbeeck, Van Rompuy, Hermy, & Van Orshoven, 2013)*

Monetization

To value or monetize this ES, the avoided cost of sewage treatment can be calculated. This value is based on the annual contribution paid by citizens to finance wastewater and rainwater drainage, as often collected through the integral water bill (Hendrix, et al., 2018). Hendrix et al. (2018) estimated the annual avoided sewage costs at €0,52 per cubic meter of rainwater that is absorbed by nature instead of drained trough the sewage system. These calculations are in line with another study, that estimated that cities spend on average US$0,62 (€0,52) per cubic meter of drained stormwater (KPMG International, 2017). Please note that the BM does not consider the avoided cost of infrastructural damage by flooding. Moreover, infrastructural investments expanding the capacity of sewage systems can be postponed or avoided by introducing more GI. The latter is also not considered within the scope of the BM, but might be relevant information for decision making processes.

3.7. Air Filtering

Introduction

This ES refers to the change in air quality by removing pollutants from the atmosphere, including ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), and particulate matter (PM_{10}, $PM_{2,5}$). Air pollution from transport, domestic heating, industry, waste incineration, etc. all contribute to the increase of respiratory and cardiovascular diseases in cities (Gómez-Baggethun & Barton, 2013). According to research from Lelieveld et al. (2015), air pollution leads to 3.3 million premature deaths worldwide each year. Furthermore, they estimated that this number will double by 2050, reaching 6.6 million premature deaths per year around the world because of air pollution (Lelieveld, Evans, Fnais, Giannadaki, & Pozzer, 2015). By implementing more green in the cities, air quality can be improved, leading to avoided health costs, and less premature deaths (Gómez-Baggethun & Barton, 2013).

By implementing more vegetation in cities, more particulate matter and toxic gases is absorbed. The influence of vegetation on air quality is determined by two different processes. On the one hand, there is the filtering process whereby air pollutants are captured from the atmosphere. On the other hand, there is the impact of vegetation on the airflow itself, whereby the wind speed, wind direction, and turbulence are locally altered, affecting concentrations of pollutants in the atmosphere (Hendrix, et al., 2018). This second process is not considered in the BM since it depends on unpredictable variables such as the weather.

Table 12: *Air filtering*

Element	Type	Unit	Air filtering (kg/m²/yr)
Green wall	Green façades	m²	0,0079
	Living wall	m²	0,0079
	Vegetated mats, felt systems, or modular	m²	0,0079
	Hydroponic green walls	m²	0,0079
	Hedges	m²	0,004
Trees and shrubs	Single tree (>12m)	amount	0,71 (kg/tree /yr)
	Single tree (6m-12m)	amount	0,71 (kg/tree /yr)
	Single tree (<6m)	amount	0,71 (kg/tree /yr)
	Broad-leaved woodland	m²	0,01 (kg/m²/yr)
	Coniferous woodland	m²	0,01
	Mixed woodland	m²	0,01
	Herbaceous plants	m²	0,004
	Shrubby plants	m²	0,004
Fruit and vegetables	Fruit tree (apple)	amount	0,71 (kg/tree /yr)
	Fruit tree (pear)	amount	0,71 (kg/tree /yr)
	Fruit tree (cherry)	amount	0,71 (kg/tree /yr)
	Fruit tree (citrus)	amount	0,71 (kg/tree /yr)
	Hedge (berries)	amount	0,004
	Green façades (grapes)	m²	0,0079
	Allotment garden (potatoes)	m²	0,002
	Allotment garden (onions and garlic)	m²	0,002
	Allotment garden (carrot and root vegetables)	m²	0,002
	Allotment garden (tomatoes)	m²	0,002
	Allotment garden (lettuce and leaf vegetables)	m²	0,002
	Allotment garden (strawberry)	m²	0,002

Element	Type	Unit	Air filtering (kg/m²/yr)
Low green	Lawn	m^2	0,002
	Amenity grassland	m^2	0,002
	Tall grass	m^2	0,002
	Flower field	m^3	0,002
Green roof	Extensive green roof	m^2	0,0077
	Intensive green roof	m^2	0,0077
Sustainable drainage systems	Rainwater harvesting	m^2	0
	Filter drain or infiltration trench	m^2	0,002
	Filter (buffer) strips or swales	m^2	0,002
	Wetlands, ponds or retention areas	m^2	0
	Soakaways	m^2	0
	Bioretention areas	m^2	0,002
	Trench-troughs or wadis	m^2	0,002
	Flowing water	m^2	0
(Semi-)permeable surface	Semi-permeable grow-through pavers	m^2	0,001
	Permeable stone/pavement	m^2	0,001
	Wood chips or bark	m^2	0
	Loose surfaces	m^2	0
	Natural playground amount	amount	0,001
	Rustic playground amount	amount	0
Grey infrastructure	Impermeable surface	m^2	0
	Storm sewage	m^3	0
	Brick wall	m^2	0
	Normal roof	m^2	0
	Concrete pond/lake	m^2	0
	Traditional playground	m^2	0

Source: *(Blanuša, Qadir, Kaur, Hadley, & Gush, 2020; Greater Manchester Combined Authority, 2021; Groentool Antwerpen, 2021; ICLEI, 2006; Perini & Rosasco, 2013)*

Quantification

The quantification of this ES is based on information gathered in the IGNITION database, the 'Groentool Antwerpen', and on research by Perini and Rosasco (2013), Blanuša et al. (2020), and ICLEI (2006) (Blanuša, Qadir, Kaur, Hadley, & Gush, 2020; Greater Manchester Combined Authority, 2021; Groentool Antwerpen, 2021; ICLEI, 2006; Perini & Rosasco, 2013). Based on these sources table 12 was compiled showing how many kilograms of pollutants per square meter each type of GI can purify from the air each year. The BM cannot distinguish between the different pollutants (O_3, NO_2, SO_2, CO and PM_{10}) as the concentrations of each pollutant can vary from day to day and are highly sensitive to geographical fluctuations.

Th BM does also not consider where GI is implemented although one should be cautious when planting vegetation in urban areas. For instance, when trees are planted in narrow streets with a lot of traffic -so called 'street canyons' – it could even result in a negative effect on local air quality due to the reduced ventilation in the street canyon (Hendrix, et al., 2018). Secondly, not every vegetation type will significantly improve air quality. According to Vierea et al., (2018), the characteristics of vegetation (vegetation structure, composition, and management) are important variables that partly determine the capacity of green spaces to purify the air and regulate climate. Vegetation types with a more complex structure (e.g., trees, herbaceous layers, and shrubs) and which do not require constant management (e.g., irrigation, pruning, and fertilization), are more suited to filter the air and regulate the climate.

Monetization

Monetization of this ES is not achievable since it is impossible to know the ratios between the various pollutants. Still, the value of air filtering strongly depends on which type of pollutant is removed. Since one pollutant is more harmful than the other (e.g., PM_{10}), the value of removing them from the air is much greater.

Nevertheless, to give some indications of the value of this ES, we summarized previous research: The value of particulate matter capture refers to the avoided health costs due to less exposure to particulate matter. This exposure leads to major effects on public health, both in terms of more diseases (respiratory and cardiovascular complaints) and shorter life expectancy. These health effects lead to increased health costs (e.g., hospitalization, medication), more illnesses, loss of productivity at work and at home, and premature death. De Nocker et al., (2010) estimated these costs calculated an external cost of 150€/kg $PM_{2.5}$ and 25€/kg $PM_{2.5\text{-}10}$ for average population densities as in Flanders in 2010. Another study in China revealed that the external costs due to $PM_{2.5}$ pollution (which is more harmful than PM_{10}), is equivalent to 0,3% to 0,9% of Beijing's regional GDP depending on the valuation method and on the assumed baseline $PM_{2.5}$ concentration. The economic loss due to premature deaths accounted for over 80% of the overall external costs (Yin, Pizzol, & Xu, 2017). According to a study from Hoveidi et al., (2013) in Tehran (Iran), the damage cost per day estimated with a 2045 kg/day or 1499 kg/day PM_{10} emission rate is around US$10,2 and US$7,45 million, respectively (Hoveidi, Aslemand, Vahidi, & Limodehi, 2013). Lastly, McPherson et al. (1999) calculated that an average tree has an annual air-pollutant uptake of 1,68kg, with an implied value of €13,46 per tree (McPherson, Simpson, Peper, & Xiao, 1999).

3.8. Biodiversity

Introduction

An important supporting ES is the creation of habitat for biodiversity: green infrastructure in cities can create new habitats for animals and plants, which results in more species that find a suitable habitat and thus in higher biodiversity. A large amount of processes is affected by changes in biodiversity including climate regulation, carbon sequestration, pollination and seed dispersal (Millennium Ecosystem Assessment, 2005).

An important remark here is that for the preservation of animals, not only the presence of green infrastructure is a defining factor, but also the size and type of vegetation. Therefore, connections between urban green and the rural ecosystems outside the urban areas will result in a much higher biodiversity. This is often not the case due to roads, railroads and large built-up areas around the cities that disrupt these connections and create a barrier for migration of the species (Bolund & Hunhammar, 1999).

Quantification

For the quantification of the supporting ES biodiversity, three components were examined, namely the extent of habitat types, structural diversity and the potential to serve as a habitat for target species. This method was developed by Prof. Jan Mertens and ing. Robbe De Beelde (De Beelde & Mertens, 2021).

Extent of habitat types

The first component to quantify is the extent of habitat types. These types are lawn, tall grass, middle green, trees, semi-permeable land, vegetable gardens and water elements. Each of these can be drawn up in QGIS. Following this, the areas of each type were exported to Excel to make an easy-to-interpret overview in the form of a radar chart. Each specific location can only have one habitat type (even though overlap such as lawns with some trees can occur) to achieve a total habitat area that is equal to the total area.

Land use diversity

The next component, land use diversity, was quantified by using a diversity index. This is a quantitative measure that indicates how many types of land use are in a dataset and simultaneously considers richness and evenness (Tucker et al., 2017). These indices are often, but not exclusively, used in ecological research as biodiversity indices. The effective number of species (ENS) is an example of such an index. ENS is an extension of the Shannon-Weaver index (Equation 1), which accounts for the evenness or entropy. The ENS transforms the Shannon-Weaver index in the more easy-to-interpret units of species (Jost, 2006). ENS is the number of species in an equivalent community (with the same Shannon index) where all species are equally abundant. In case of a perfectly even community, the ENS will be equal to the number of species (S) in the test area (Zeleny, 2021). For example, a certain parcel with 2 species that each cover 50 % of the area, will have an ENS equal to 2, whereas a parcel covered for 99 % by species 1 and for 1 % by species 2 will have an ENS equal to 1.06 (De Beelde & Mertens, 2021).

As estimating population sizes would be too elaborate for a biodiversity estimation, the indices were used to assess land use diversity in this thesis. The effective number of habitat types is calculated through $D = \exp H'$ (Equation 2). The maximal number of habitat types is equal to the number of different habitats of which the area is not 0 m².

Shannon-Weaver index (H'):

$H' = -\sum_{i=1}^{S} p_i \cdot \ln p_i = -\sum_{i=1}^{S} \frac{n_i}{N} \cdot \ln \frac{n_i}{N}$ (Equation 1)

with

i = species number, in this case the cover type (such as lawn or trees)

S = the number of species in the researched area, in this case the number of habitat layers (with an area larger than 0)

ni = degree of coverage by species i, in this case the total area of habitat layer i

N = total degree of coverage, in this case the total area (or the sum of all habitat layer areas)

Effective number of habitat types (D):

$D = \exp H'$ (Equation 2)

Potential habitat for target species

The last component of habitat biodiversity quantification focuses on the species itself. Some target species were selected (34 in total) from different taxonomic groups: birds, butterflies, bees and amphibians (Table 13). The species selection was based on different parameters, such as various characteristics of the species, different habitat requirements, availability in the countries, observations, etc. Multiple experts helped with this selection and the requirements. In the tool, the potential of the presence of these target species is calculated. This was done by examining the target species' minimum habitat requirements and their needs based on their life cycles (food supply, nesting opportunity and places for overwintering or shelter) (NSCiti2S, 2020; Weisser & Hauck, 2017). The user of the tool only needs to fill in "yes" or "no" next to a list of green elements, such as forest, vegetable garden, bird house etc. to check if the test area has the potential of being a suitable habitat for a certain target species. This is done by counting the number of present green elements that contribute to a suitable habitat for a certain target species and then taking the ratio of this number and the total number of green elements that make a perfect habitat for this target species. The result is a percentage that represents the suitability of the habitat for that particular target species. Lastly, these percentages of the target species are put into categories to see what proportion of the group will find the test area a suitable habitat (De Beelde & Mertens, 2021).

Table 13: *Target species used in the habitat quantification per taxonomic group (De Beelde & Mertens, 2021; Naessens, 2021).*

Birds			**Butterflies**	**Bees**	**Amphibians**
Greenfinch *Chloris chloris*	Jay *Garrulus glandarius*	Dunnock/Finch *Prunella modularis*	Peacock *Aglais io*	Tawny mining bee *Andrena fulva*	Common toad *Bufo bufo*
Wood Pigeon *Columba palumbus*	Great Tit *Parus major*	Collared dove *Streptopelia decaocto*	Brown Sandpiper *Maniola jurtina*	Orange-tailed mining bee *Andrena haemorrhoa*	Alpine newt *Ichthyosaura alpestris*
Great spotted woodpecker *Dendrocopos major*	House Sparrow *Passer domesticus*	Blackcap *Sylvia atricapilla*	Large Skipper *Ochlodes sylvanus*	New garden bumblebee/ tree bumblebee *Bombus hortorum*	Smooth newt *Lissotriton vulgaris*
Robin *Erithacus rubecula*	Chiffchaff *Phylloscopus collybita*	Wren *Troglodytes troglodytes*	Speckled Wood *Pararge aegeria*	Ivy bee *Colletes hederae*	Green frog *Pelophylax kl. esculentus*
Common Coot *Fulica atra*	Magpie *Pica pica*	Blackbird *Turdus merula*	Great cabbage white/ small cabbage white *Pieris rapae*	European orchard bee *Osmia cornuta*	Common frog *Rana temporaria*
Moorhen *Gallinula chloropus*	Green Woodpecker *Picus viridis*	Song Thrush *Turdus philomelos*	Large Skipper *Polygonia c-album*		

Monetization

Monetization is outside of the scope of the BM. In case the user desperately wants to calculate the value of biodiversity they can use the TEEB (The Economics of Ecosystems and Biodiversity) framework to map the economic benefits of biodiversity or the incremental costs of biodiversity loss.

3.9. Aesthetic appreciation

Introduction

This ES refers to the attractiveness of the area and desirability to live in the area (Horton, Digman, Ashley, & McMullan, 2019). GI and nature improves the living quality and the 'experience value' of residents. For instance, a study in the UK found that the aesthetic quality of local parks, playing areas, and neighbourhood green relates to older people's life satisfaction. Moreover, having safe routes and/or paths to these green spaces is correlated with more walking behaviour, regardless of a person's age, physical ability, and education (Sugiyama, Thompson, & Alves, 2008). In addition, people feel safer if there are trees lining the sidewalk since they can serve as a protective barrier between pedestrians and vehicles. When people feel safer, they will likely walk more, which in turn encourages neighbourhood interactions fostering the development of community identity (ICLEI, 2006).

McPherson et al. (1999) estimated the yearly aesthetics value of the 91,179 trees in Modesto California, and found a value of €14,30 per tree (McPherson, Simpson, Peper, & Xiao, 1999). Another study in Barcelona calculated the value of cultural ES for the biggest urban park of the city, Montjuïc park. By using the travel cost method, the researchers estimated the value of aesthetic appreciation at USD$1.70 (€1,44) per visit (Langemeyer, Baró, Roebeling, & Gómez-Baggethun, 2015).

Quantification

In the BM, users score each scenario on statements gauging the impact on indicators influencing the aesthetic experience people (will) enjoy. Users are invited to alter the importance factors (1 being lowest local importance, 5 highest local importance) that are put on different statements to reflect the importance that local stakeholders give to different aspects. Based on these importance factors, a statement is given a weight. The weights are linearly set-up between 1 (lowest importance) and 2 (highest importance), this way users have the freedom to adjust the model slightly to the local preferences. A weighted average is calculated and reflects a scenario's score on aesthetic appreciation.

Monetization

The monetization of this ES is based on research by Wang et al. (2014) who concluded from their literature study that people are willing to pay between €1,60 and €20 per person per year to live in an attractive landscape (Wang, Bakker, de Groot, & Wörtche, 2014). These numbers result from both hedonic pricing and contingent valuation methods. The BM assumes a linear progression and calculates a value between €0 and €20 per person per year depending on the answers to the aesthetic appreciation questions (the higher the overall score on aesthetic appreciation, the higher the monetary value) and multiply it by the number of people living in the project area.

3.10. Health

Introduction

Nature and urban GI are known to support both physical and mental health. Kaczynski and Henderson (2007) reviewed over 50 studies regarding the effect of nature on physical activity and found that nature contributes to more physical activity and consequently a healthier community (Kaczynski & Henderson, 2007). Physical exercise is also essential to lower the rate of obesity in the world. According to the WHO (2020) worldwide obesity has nearly tripled since 1975. Furthermore, in 2016, over 1.9 billion adults (individuals of 18 years and older), were overweight and 650 million were obese (WHO, 2020). Moreover, physical inactivity, increase the risk of noncommunicable diseases (e.g., heart diseases, diabetes, cancer, stokes, etc.) with 20 to 30% and shortens people's lifespan by 3 to 5 years. Physical inactivity is not only harmful for the individual, but it also burdens society through the hidden and growing cost of medical care and loss of productivity (WHO, 2020). Regarding mental health, several influential studies prove the impact of green infrastructure on mental state. Illustrating the relevance of residential green space, research with over 900.000 people in Denmark has shown that children growing up in urbanized environments with the lowest level of green space have 55% higher risk of developing a psychiatric disorder (Engemann, et al., 2019).

By promoting and facilitating physical activity, many health-related issues and costs can be avoided. For instance, Ellaway et al. (2005) found a positive relation between higher levels of neighbourhood greenery and more physical activity, as well as reduced levels of self-reported overweight or obesity (Ellaway, Macintyre, & Bonnefoy, 2005). Another study also found that outdoor physical activity predicted lower somatic anxiety, whereas indoor physical activity predicted higher somatic anxiety (Lawton, Brymer, Clough, & Denovan, 2017). Furthermore, Hartig et al. (2003) study showed that walking in a natural setting had positive emotional and cognitive outcomes (e.g., less anger, greater stress reduction, more attention, etc.) in comparison with walking in urban areas (Hartig, Evans, Jamner, Davis, & Garling, 2003). A similar study by Mayer et al. (2009) compared the effects of a 15-min walk in a natural setting with a similar walk in an urban setting and found that the emotional well-being, attentional capacity and the ability to reflect on a life problem of the people who walked in a natural setting was enhanced in comparison to those who walked in an urban settings (Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009). These results are closely related to the result of a previous study by Pretty et al. (2007). They found that physical activities (e.g., walking, horse riding, cycling, etc.) in a natural setting led to a significant improvement in self-esteem and total mood disturbance. In other words, physical activities in a green environment generate a wide range of benefits for human health and mental well-being (Pretty, et al., 2007). Even passive activities in nature, such as sitting on a bench or being surrounded by green, have positive effects on well-being (Wolf & Housley, 2016).

Quantification

To quantify this ES the BM relies on the concept of 'disability adjusted life years' (DALY). A DALY is an aggregated health metric that is used to value the changes in public health caused by environmental pollution. DALYs are based on experts' assessment rather than the citizen's point-of view or willingness-to-pay (Stassen, Torfs, Maris, & Dijkmans, 2007; WHO, 2022).

Calculations are based on (Maas, 2009) and similar to Hendrix et al. (2015). It was found that a 10% increase in green space within a 1 km radius from home, health effects equal 2,46 DALY per 1000 inhabitants. This factor is made up of a mental health effect (1,14 DALY/1000 inh) and a physical health effect (1,32 DALY/1000 inh). These values are converted to reflect the impact of a hectare of green space within 1000m radius from the home (per 1000 inhabitants). This leaves us with 0,078 DALY per 1000 inhabitants per hectare of green space within a 1 km radius. This relation is assumed to be linear, similar to NWV (Hendrix, et al., 2015). Using the surfaces of green space in different scenarios and the number of inhabitants within a 1000m radius to the project site, the impact on health effects expressed in DALY is calculated.

Monetization

Stassen et al. (2007) calculated the price per DALY at €105.000 (the finding was actualised to early 2022 price levels) (Stassen, Torfs, Maris, & Dijkmans, 2007). Knowing the number of DALY as well as the price per DALY allowed the monetization of this ES.

3.11. Recreation and tourism

Introduction

Areas suitable for local (urban) recreation are often found in human-influenced environments such as parks, meadows, forests, grasslands, and water areas. In an urban environment, even small green areas can be significant for human recreation especially when it comes to young people. According to Mäkinena and Tyrväinen (2008), adolescents valued green spaces differently from adults. Young people appreciated the beauty of the environment, calmness, and opportunities for outdoor activities whereas adults perceived it as transitory areas or green elements in the housing environment (Mäkinen & Tyrväinen, 2008). Urban green infrastructure is also important for tourism. According Terkenli et al. (2017; p.191), "the landscape of great cities includes, and is often determined by, [...] the urban green infrastructure". For instance, a stroll along the Champs Elysees in Paris, a jog in High Line Park in New York, or a picnic in Hyde Park in London, these are a few examples of how green space in urban areas enrich the experience of tourists and residents (Terkenli, et al., 2017). For instance, a study in Barcelona calculated the value of cultural ES for the biggest urban park of the city, Montjuïc park. By using the travel cost method, the researchers estimated the recreational value of the park at USD$9,85 per visit and the touristic value at USD$1,30 per visit (Langemeyer, Baró, Roebeling, & Gómez-Baggethun, 2015). The value of this ES strongly depends on the kind and scale of nature or GI and where it is situated. Most studies monetizing the recreational and touristic value of nature use the travel cost method.

Quantification

The quantification of this ES is based on two methods. The first focusses on recreation. Depending on the population density of a certain region or city, the BM can estimate the number of visits. According to research, people living within a 300m range from a GI project will visit it 10 times a year, people living within a 300-600m range will visit the GI project 5 times a year, and people living in a 600-1200m range will visit it once a year (Hendrix, et al., 2018).

The second method focusses on tourism, if the user has indicated that tourism is an important objective of the GI project. The value of tourism is based on the number of overnight stays booked by tourists in the city. The BM assumes on average 0,3 visits per overnight stay, based on Dutch research by de Vries, Maas, and Krame (2009) (Vries, Maas, & Kramer, 2009).

Monetization

According to de Vries, Maas, and Kramer (2008), each visit can be valued at €1,5 per visit. By multiplying the number of recreational and touristic visits to the GI project with €1,5, this ES can be monetized. Please note that the BM makes does not consider the size nor the level of ambition of the GI projects.

3.12. Real estate prices

Introduction

The environmental and cultural benefits generated by urban green space are often capitalized into the values of residential and commercial properties (Sander, Polasky, & Haight, 2010). Although many studies found evidence for an increase in real estate prices in proximity to trees, parks, and forests, the effect depend on the kind of GI and on the distance of the property to the GI.

A study by Donovan and Butry (2010) found that street trees within 30m of a house, add on average USD$8.870 to the sales price of that property (which is around a 3% increase). Furthermore, they found that houses in close proximity to green space are sold on average 1,70 days faster than other similar houses with no green space in proximity (Donovan & Butry, 2010). A more recent study estimated that the sales price of a property increases with USD$11.583 in proximity of tree canopy coverage (which is around a 4% increase). Both studies were conducted in Portland and used the hedonic pricing method (Netusila, Levin, Shandas, & Hart, 2014). Another study in the counties of Dakota and Ramsey calculated that a 10% increase in tree cover within 100m of a property increases average sale price of the house by USD$1.371 (0.48%) and within 250m increases sale price by USD$836 (0.29%) (Sander, Polasky, & Haight, 2010). Lastly, after building High Line Park in New York, property values increased with 103% between 2003 and 2011 (Gore, Eadson, Ozdemiroglu, Gianferrara, & Phang, 2013).

In Salo, Finland, property values are estimated to decrease by 5,9% on average with each 1km increase in distance to the nearest forest. Furthermore, properties with forest views are 4,9% (or USD$3,731) more expensive than similar properties without a forest view (Tyrvainen & Miettinen, 2000). A similar study by Wu et al. (2015) in Shenzhen, demonstrated that the standard residential price decreases with US$3.356 as the distance of the house to the park increases by 1km (Wu, Wang, Li, Peng, & Huang, 2015). Lastly, in Aotearoa, New Zeeland, Vesely (2007) estimated people's willingness to pay to avoid 20% decrease in urban trees using the contingent valuation method and found that household average annual WTP was USD$143 for a three year period (Vesely, 2007). Most studies used the hedonic pricing method or the contingent valuation method to monetize the effect of GI on housing prices.

Quantification

To quantify this ES, extensive literature study has been conducted. Based on various European studies an overview was made of the average percentual increase in housing prices as a result of GI (see table 14). For instance, a study in the Netherlands found that houses overlooking water elements or green space were respectively 8-10% and 6-12% more expensive than similar houses that did not have that view (Luttik, 2000). Another study in the UK demonstrated an average 11,30% increase in house prices if the house overlooked a park (The Mersey Forest, Natural Economy Northwest, CABE, Natural England, Yorkshire Forward, The Northern Way, Design for London, Defra, Tees Valley Unlimited, Pleasington Consulting Ltd, and Genecon LLP (2010), 2018). Moreover, evidence from Finland and Italy revealed an average 5% and 2,5% increase in housing prices if the house overlooked a forest or a green wall (Perini & Rosasco, 2013; Tyrvainen & Miettinen, 2000). Lastly, the IGNITION database demonstrated that houses in a street with trees were on average 5% more expensive then houses in a street without trees (Greater Manchester Combined Authority, 2021).

Table 14: *Real Estate Prices*

Houses overlooking green/blue elements	Percentual increase in house price	Location of study	Source
Houses overlooking water	9%	Netherlands	Luttik, 2000
Houses overlooking open green space	9%	Netherlands	Luttik, 2000
Houses overlooking a park	11,30%	UK	Ecosystems Knowledge Network, 2021
Houses overlooking a forest	5%	Finland	Tyrväinen & Miettinen, 2000
Houses with/overlooking a green wall	2,50%	Italy	Perini & Rosasco, 2016
Houses in a street with trees	5%		Greater Manchester Combined Authority, 2021

Monetization

For the monetization of this ES the BM relies on the average house prices in/around the project area as well as the number of houses overlooking different types of GI. Knowing this information – which will need to be provided by the user – and the average percentual increase in housing prices of houses overlooking different types if GI, the monetary value will be calculated. Please note that if a house overlooks more than one type of GI, the BM will use the highest percentage.

3.13. Education and raising awareness

Introduction

Green environments allow us to experience, enjoy and learn about nature and the environment. For example, students can learn about the functioning of ecosystems. Moreover, the green infrastructure project can aid in raising awareness about current threats (e.g., air quality issues, rising sea level, etc.) but also about good practices and potential solutions.

Environmental education, both formal (e.g., in classes, museums, or educational centres) and informal (e.g. field classes, workshops, and during private travels), are becoming increasingly important (Mocior & Kruse, 2016). Although it is more challenging to organize outdoor learning opportunities, it is beneficial for the learning process of students. According to some social sciences studies, learning about the environment outdoors, facilitates students to remember and process the knowledge due to the usage of all the senses (learning by doing) (Mirrahimi, Tawil, Abdullah, Surat, & Usman, 2011; Spalie, Utaberta, Abdullah, Tahir, & Ani, 2011). Furthermore, outdoor learning provides students the opportunities to improve their academic achievement and social emotional intelligence (Mirrahimi, Tawil, Abdullah, Surat, & Usman, 2011). Additionally, environmental education is known to contribute to a better understanding of the environmental risks (Bangay & Blum, 2010), it promotes public participation in decision making , and it makes people more aware of the need for nature conservation (Hiwasaki, Luna, Syamsidik, & Shaw, 2014).

In sum, urban green infrastructure has the potential to improve the educational achievements of students, which contributes to creating a better qualified and more highly skilled workforce. These benefits will translate in valuable business investments and higher salaries. In other words, urban green space is a valuable education resource offering learning and employment opportunities (Molla, 2015). A study in Barcelona calculated the value of this ES for the biggest urban park of the city, Montjuïc park. By using the travel cost method, the researchers estimated the value of environmental learning at USD$2,69 per visit (Langemeyer, Baró, Roebeling, & Gómez-Baggethun, 2015).

It is clear that nature and urban green infrastructure can create an educational value. However, this ES is challenging to value or monetize because ‘environmental learning’ generates a low monetary value but a high non-monetary value (Langemeyer, Baró, Roebeling, & Gómez-Baggethun, 2015). So far, a very limited number of examples of assessments of the use of landscape educational values can be found in the literature. Mocior and Kruse (2016) reviewed the indicators and criteria used in the literature to assess this educational ES. Some of the indicators were: annual budget for environmental education; the frequency of excursions with environmental education purposes; the location (the distance to a school or other educational centre), the history of educational use and the presence and the quality of the educational infrastructure; and so on (Mocior & Kruse, 2016).

Quantification and monetization

Quantification and monetization of this ES is not possible with the BM. When developing the BM we found very little reliable methods. The methods that generated credible results required a lot of information from the user and were too complex to incorporate in the BM.

3.14. Social Cohesion

Introduction

Green infrastructure improves social cohesion by strengthening the networks of (in)formal relationships among neighbourhood residents that foster a nurturing and mutually supportive human environment (CNT, 2011). For example, parks and recreational areas are important meeting places for inhabitants (e.g. children, older people, etc.). Furthermore, if GI projects include citizens in the development of the project, these social ties will become even more important.

Kweon, Sullivan, and Wiley (1998) demonstrated that the physical environment could be designed to promote older adults’ (ages between 64 and 91 years) social integration with their neighbours. The results revealed that the use of public urban green spaces predicted both the strength of neighbourhood social ties and sense of community (Kweon, Sullivan, & Wiley, 1998). This relationship between a greener environment and better social ties also holds true among the elderly who are particularly prone to isolation. For instance, elderly living in public housing with greater exposure to green common areas report stronger ties with neighbours and friend, a stronger sense of community and a greater involvement with neighbourly activities (Coutts & Hahn, 2015). The quality and quantity of individuals’ social relationships has been linked not only to mental health but also to both morbidity and mortality. Holt-Lunstad, Smith, and Layton reviewed 148 studies and found that people with stronger social ties have 50% less risk of death in comparison with people with weak social ties. This effect is comparable with quitting smoking (Holt-Lunstad, Smith, & Layton, 2010).

Quantification and monetization

Quantification and monetization of this ES is not possible with the BM for various reasons. Researchers acknowledge a range of limitations regarding studies on social cohesion and GI. For instance, it is challenging to define who counts as a neighbour or community member and how geographical boundaries intersect with social relationships that occur outside of project area. Moreover, social cohesion is measured in multiple ways throughout the literature, and it does not appear that there is a standard way to measure social cohesion, social capital nor community engagement. In addition, there are many factors such as age, economic status, cultural background, etc. underpinning social interactions. Lastly, the influence of spatial and temporal variation in social networks may also present limitations to this research topic (Jennings & Bamkole, 2019). For the reasons mentioned above, this ES will not be quantified nor monetized in the BM.

3.15. Attractor for companies and investment

Introduction

This ES refers to the fact that green environments result in an attractive settlement for companies and employees to establish themselves in a specific region. In addition, several studies indicate that green space improves physical and mental health, reducing absenteeism and increasing productivity and motivation of employees (Aertsens, et al., 2012). Furthermore, given that green areas attract people for leisure and recreation purposes, surrounding businesses might experience an increase in revenues.

Trees in business districts can attract more people as a result of the positive effect of nature on people's mood. Healthy and aesthetically pleasing trees in a business's area imply that those businesses do not only care about the quality of people inside their doors, but also care about the quality of the outside community (ICLEI, 2006). Moreover, a study in London discovered that the newly installed GI schemes positively influenced the retail business. Interviews also revealed that GI attracted more customers and enhanced visitors' experience. This was particularly the case for the businesses located adjacent to major GI projects (Cinderby & Bagwell, Exploring the co-benefits of urban green infrastructure improvements for businesses and workers' wellbeing, 2018). Another study by Joye et al. (2010) concluded that that in-store and out-of-store greenery attract consumers which can provide businesses with a strategic advantage (Joye, Willems, Brengman, & Wolf, 2010).

Quantification and monetization

Quantification and monetization of this ES is not possible with the BM due to the complexity of quantifying and monetizing this ES. Still, Cinderby and Bagwell (2018) found that business managers perceived increases in customer footfall and sales because of GI. Moreover, they reported that accessible green space in office settings "led to improvements in morale, team interaction and workplace satisfaction among staff members able to access the improvements. Increased GI was seen as improving uptake of company environmental policies such as energy saving or recycling among staff by their managers" (Cinderby & Bagwell, 2018, p. 126). They also found that GI in proximity of the workspace improved self-reported workplace happiness and greater interaction with nature spaces (Cinderby & Bagwell, 2018). Nevertheless, there is still a lack of research about the benefits for businesses in terms of customer experience, increased sales and investments, or improvements in staff wellbeing from installing green infrastructure in a European cities. In addition it is challenging to quantify and value this ES. The impact of GI on this ES depends on various variables including how many businesses are in/around the project area, which kind of businesses, how many customers are expected daily, the average sales and profit, the scale of the GI project, how much GI is already installed in the neighbourhood, etc. This information is hard to gather for LA, therefore this ES will not be quantified nor valued in the BM.

Some of the cultural ecosystem services are not quantifiable, or very challenging to quantify or monetize for several reasons:

- overlap between the different cultural ecosystem services, which could lead to double counting certain benefits. In order to avoid this, we opt to extensively explain the added value of cultural ecosystem services in qualitative terms but provide conservative estimations in quantitative or monetary terms.
- the value that is added through cultural ecosystem services is highly dependent on the context.
- the benefits gained through facilitating cultural ecosystem services may be beyond valuation. They are connected to human wellbeing, sense of place, feeling of mental and spiritual health, etc. This does not mean worthless, but it does mean unmeasurable.

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Appendix – Landscape types

Green wall

- **Green façades:** A green façade is created by growing climbing plants up and across the facade of a building, either from plants grown in garden beds at its base, or by container planting installed at different levels across the building.
- **Living wall:** Living walls are created by attaching growing media to the vertical wall, and this relatively new technique is classified as 'continuous living walls' or 'modular living walls'. Constructed with planter boxes or felt; these do not require the plants to be climbing, they often need to be irrigated. The greenery is often planted in a growth medium consisting of soil, stone, or water.
- **Vegetated mats, felt systems, or modular:** A subset of living walls - built using mat, modules or felt systems which provides pockets for plug plants to be grown through. These often require irrigation systems and may need professional installation and maintenance.
- **Hydroponic green walls:** A hydroponic system provides an inert growing medium to which the plants physically anchor, such as a horticultural foam, a mineral fibre or a felt mat. These materials can act as a water retentive sponge, although the more they soak up the heavier the system becomes. The hydroponic system means that there is no structural decay of the growing medium, no salt build up from fertilisers and nutrients are supplied in a precise and controlled manner.
- **Hedges:** A row of bushes or small trees, usually along the edge of a garden, field, or road.

Note: *picture 1 denotes a green façade; picture 2 a living wall; picture 3 vegetated mats, felt systems, or modular; picture 4 a hydroponic green wall; and picture 5 a hedge.*

Trees and shrubs

- **Single tree (>12):** A very large tree
- **Single tree (6-12):** A medium size tree
- **Single tree (<6):** A small tree

Note: *(1) single tree (>12); (2) single tree (6-12); (3) single tree (<6)*

Woodland

- **Broad-leaved woodland:** Vegetation formation composed principally of trees, including shrub and bush understorey, where broad-leaved species predominate.
- **Coniferous woodland:** Vegetation formation composed principally of trees, including shrub and bush understorey, where coniferous species predominate.
- **Mixed woodland:** Vegetation formation composed principally of trees, including shrub and bush understorey, where neither broad-leaved nor coniferous species predominate.
- **Herbaceous plants:** Herbaceous means that the plant has non-woody stems that reach their full height and produce flower within one year, before dying back over the winter and then reappearing the following spring ready for a repeat performance. The term perennial essentially means that the plant will live for more than two years.
- **Shrubby plants:** A shrub or bush is a small- to medium-sized perennial woody plant. Unlike herbaceous plants, shrubs have persistent woody stems above the ground. Shrubs can be deciduous or evergreen. They are distinguished from trees by their multiple stems and shorter height, less than 6 m-10 m (20 ft–33 ft) tall.

Note: *(1) Broad-leaved woodland; (2) Coniferous woodland; (3) Mixed woodland; (4) Herbaceous plants; and (5) Shrubby plants.*

Fruit and vegetables

- **Fruit tree (apple)**
- **Fruit tree (pear)**
- **Fruit tree (cherry)**
- **Fruit tree (citrus)**
- **Hedge (berries)**
- **Green façades (grapes)**
- **Allotment garden (potatoes)**
- **Allotment garden (onions and garlic)**
- **Allotment garden (carrot and root vegetables)**
- **Allotment garden (tomatoes)**
- **Allotment garden (lettuce and Leaf vegetables)**
- **Allotment garden (strawberry)**

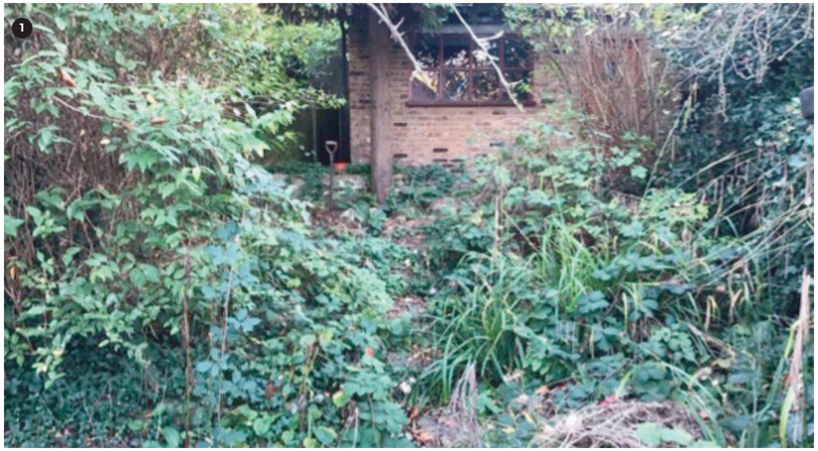
Low Green

- **Flowerfield:** a field or large planter with different species of flowers.
- **Lawn:** an area of short, mown grass in a yard, garden, or park.
- **Tall grass:** any of various grasses that are characterized by its tall stature of at least 30cm.
- **Amenity grassland:** Amenity grassland is usually intensively managed, closely mown grassland found in parks, sports grounds, village greens or around buildings.

Note: *(1) Flowerfield; (2) Lawn; (3) Tall grass; (4) Amenity grassland*

Overgrown

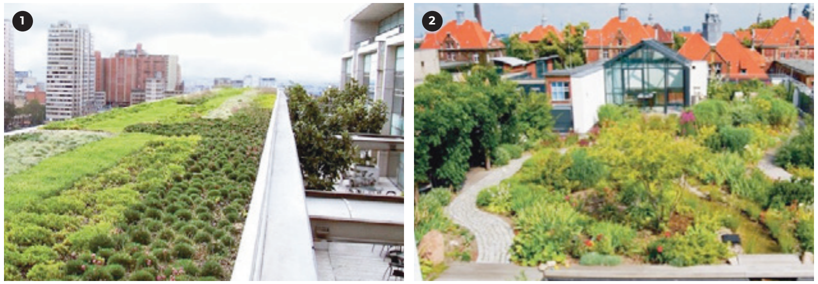
- **Overgrown:** an overgrown area is an area covered with a lot of untidy plants because it has not been looked after.



Note: *(1) Overgrown*

Green roof

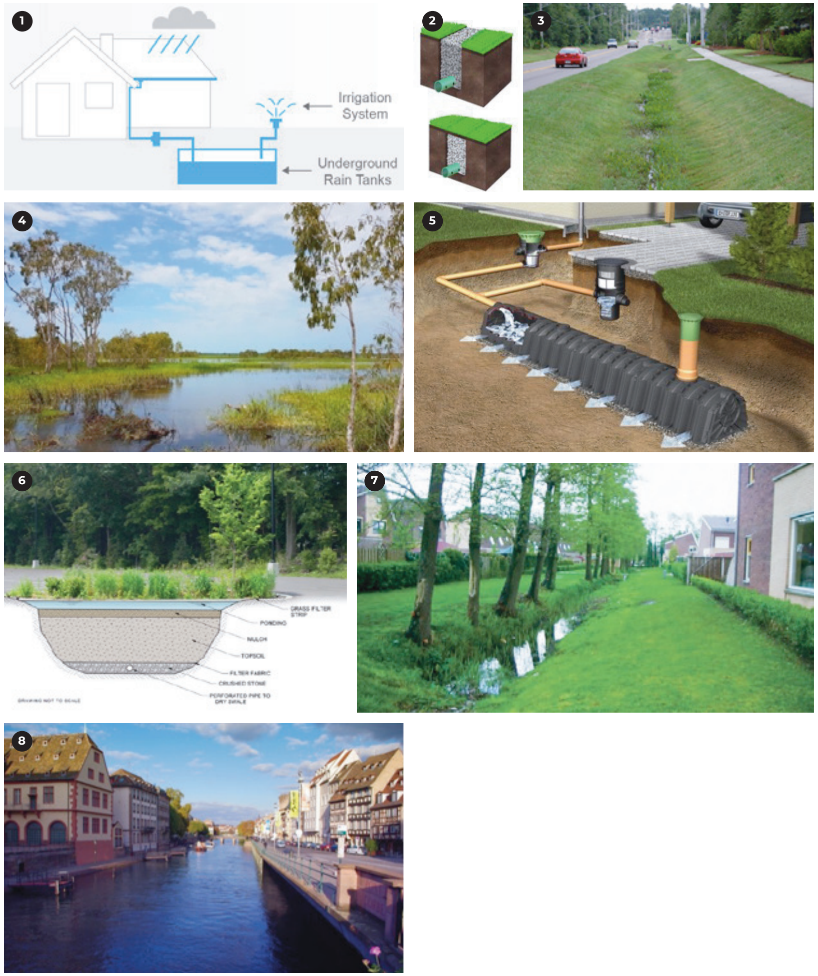
- **Extensive green roof:** an extensive green roof is lightweight minimizing the amount of structural changes needed to create it. The extensive green roof is not designed for situations where there is a lot of foot traffic and it is not well suited to growing vegetables. Extensive green roofs use a very shallow growing medium to support plants in the grass and sedum families. They fit well on roofs with shallow to moderate slopes (flat to 4 inches in 12 pitch)
- **Intensive green roof:** An intensive green roof system is characterized by its variety of vegetation ranging from herbaceous plants to small trees with professional maintenance and advanced green roof irrigation systems. A typical growing medium depth of an intensive green roof is 6 inches or more. Intensive green roofs offer a great potential for design and biodiversity.



Note: *(1) extensive green roof; (2) intensive green roof*

Sustainable drainage systems

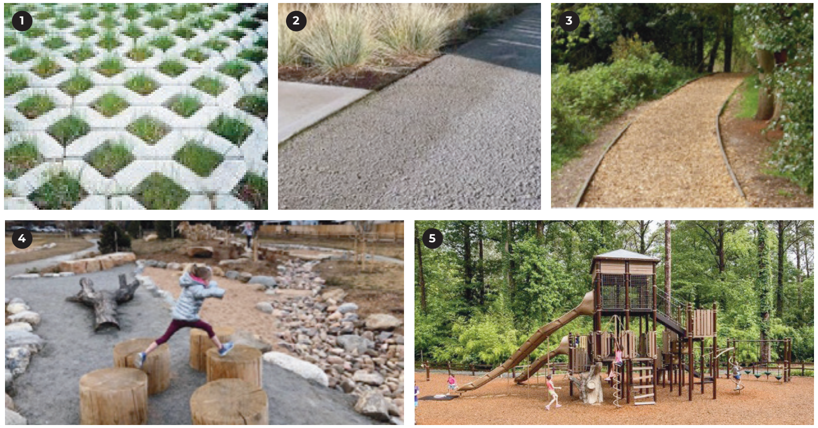
- **Rainwater harvesting:** Direct collection of rainwater that can be used for toilet flushing, irrigation, etc.
- **Filter drain or infiltration trench:** Linear drains/trenches filled with permeable material.
- **Filter (buffer) strips or swales:** (shallow) vegetated strips/ channels of sloping ground for taking runoff away from paved areas and filtering solids.
- **Wetlands, ponds or retention areas:** Usually contain (shallow) standing water but have bankside and marginal vegetation.
- **Soakaways:** Sub-surface structures that store and infiltrate runoff.
- **Bioretention areas:** Vegetated areas that collect and temporarily store runoff with the express purpose of treating it.
- **Trench-troughs or wadis:** A combination of infiltration trenches and underdrained conveyance swales used where infiltration capacity is low.
- **Flowing water:** all rivers, streams and other flowing water examples fall under this category.



Note: *(1) Rainwater harvesting; (2) Filter drain or infiltration trench; (3) Filter (buffer) strips or swales; (4) Wetlands, ponds or retention area; (5) Soakaways; (6) Bioretention areas; (7) trench-troughs or wadis; (8) Flowing water*

(Semi-)permeable surface

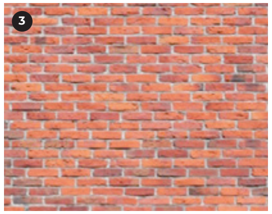
- **Semi-permeable grow-through pavers:** Grow-through pavers are an alternative to asphalt, concrete, and traditional pavers. They’re made of concrete or recycled plastic with open cells that allow grass to grow through them. They’re a porous, eco-friendly option for driveways and parking areas.
- **Permeable stone/pavement:** As for infiltration systems but with porous paving. Remove pollutants retaining them in upper soil layers.
- **Wood chips or bark:** Woodchips and bark are small- to medium-sized pieces of wood/bark which can be used in playgrounds or to form paths.
- **Natural playground:** A natural playground is a play environment that consists of elements and textures from the earth such as tree logs, tree stumps, boulders, plants, drainage paths, among others instead. Moreover, natural playgrounds are built on permeable surface.
- **Rustic playground:** A rustic playground has similar appliances as a ‘normal’ playground, but all made of natural materials such as wood.



Note: *(1) Semi-permeable grow-through pavers; (2) Permeable stone/pavement; (3) Wood chips or bark; (4) Natural playground; (5) Rustic playground*

Grey infrastructure

- **Impermeable surface:** impermeable surface means a surface that has been compacted or covered with a layer of material making the surface highly resistant to infiltration by water, such as compacted sand, rock, gravel, or clay and conventionally surfaced streets, roofs, sidewalks, parking lots, and driveways.
- **Storm sewage:** Sewerage system consists of pipes, pumps for collection of wastewater, or sewage, from a community. Modern sewerage systems fall under two categories: domestic and industrial sewers and storm sewers.
- **Brick wall:** immovable wall of bricks.
- **Normal roof:** the structure forming the upper covering of a building.
- **Concrete pond/lake:** Concrete ponds/lakes are constructed using cement, blocks and aggregate of suitable ratio. The water can not inflitrate in the soil.
- **Traditional playground:** A traditional playground contains manufactured equipment made of metal or brightly colored plastic. The equipment includes climbers, monkey bars, slides, swings, and teeter-totters (seesaws). The playground has limited permeable surface.



Note: *(1) Impermeable surface; (2) Storm sewage; (3) Brick wall; (4) Normal roof; (5) Concrete pond/lake; (6) Traditional playground;*

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