URBAN ECOSYSTEM SERVICES: LET NATURE DO THE WORK

A SUMMARY OF C/O CITY BY VARIS BOKALDERS AND MARIA BLOCK

C/O CITY – MANIFESTO

Cities are amazing, so many people living together and achieving so much. More than 50 % of the world's population live in cities, and this percentage is increasing all the time. But even in cities we are dependent on nature for food, clean water, fresh air and a regulated climate. If we are going to continue to live and thrive in cities, we need nature there as well.

Cities that function well are full of life, not only human life, but a rich diversity of life forms and habitats – grass, bumble-bees, trees, squirrels, birds that sing, plants that bloom, streams that purify, lush parks, shady groves, and shrubs that muffle noise. Nature in cities is not just decoration, it provides a vital, living infrastructure, as important as power grids and public transport. So we need to care for, protect and develop nature in cities, so it can take care of us.

The C/O City project aims to highlight the value of nature in cities – the biological, social and, not least, economic value – and to formulate a new vision of what cities should look like. We want to inspire and influence, to create new models and tools, and to provide concrete examples. We want to make it easy to plan and build cities where people and nature live in harmony.

We are representatives of organisations involved in all stages of city development, from ideas and plans to finished buildings, streets and parks.

We are experts with extensive experience in our respective fields. In addition we are passionate about improving quality of life for future generations of urban dwellers by creating environments in which people take care of nature, so that nature can take care of people.

We want to make cities even more amazing, for ourselves and for future generations.

FACTS ABOUT C/O CITY

The purpose of C/O City is to create tools for assessment, planning and use of ecosystem services in urban development to maximise benefits for society. The project is a response to the challenge "Sustainable, Attractive Cities" within Vinnova's "Challenge-driven Innovation" programme.

This project started in August 2011 and phase 3 will end in September 2017. The city of Stockholm was project owner, with partners NCC, the city of Malmö, SP Technical Research Institute of Sweden, White Architects, WSP, U&We, Albaeco, Esam and Ekokultur. The vision was to raise awareness of the potential of ecosystem services to increase the resilience of cities, while contributing to world-class sustainable urban development in Sweden.

The goals were to make visible and quantify urban ecosystem services, to develop concrete planning and monitoring tools, and to produce data to demonstrate the connections between urban ecosystem services and resilience.

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BACKGROUND
C/O CITY

TOOLS FOR GREEN INFRASTRUCTURE

One outcome of the C/O City project is the further development of tools and methods for working with the Biotope Area Factor, for which the quantification and valuation of ecosystem services are central. The project has also developed participatory methods for the design, planning and financing of green areas and structures to support ecosystem services and biodiversity in urban environments. Specifically, experiences from installation of green roofs and walls have been evaluated.

The tools and methods developed by C/O City include:

PLANNING TOOLS

Cities, municipalities and private actors are interested in working with ecosystem services when planning housing, commercial buildings and infrastructure projects. New tools are needed for working with ecosystem services in all stages of the planning process. C/O City has developed a Biotope Area Factor for public land and developed a handbook on how ecosystem services can be integrated into planning processes. We analysed how ecosystem services can be dealt with in the certification system BREEAM Communities, BREEAM-SE and CEEQUAL, and developed a method for monitoring ecosystem service functions, inspired by the Cities Biodiversity Index (CBI). The project has also developed a participatory method for optimizing and financing ecosystem services in cities.

QUANTIFICATION OF URBAN ECOSYSTEM SERVICES

C/O City wants to show the advantages of urban ecosystem services. Quantification is important if planning processes are to integrate and strengthen ecosystem services in cities. We believe that visualizing and communicating the ecological, economic and social values of ecosystem services will increase interest among urban planners, architects, developers and residents in using green infrastructure to complement the traditional grey infrastructure.

GREEN ROOFS AND WALLS

Knowledge within the construction industry about how green roofs and walls influence moisture and energy use needs to be improved. C/O City has evaluated various solutions for green roofs and walls to see how they influence moisture protection in the building envelope and energy consumption. We have also carried out interviews to gather information about experiences of construction and ongoing management processes, and views from residents about their experiences of the indoor environment.

C/O City has tested and developed ecosystem services, for example in the new city district of Stockholm Royal Seaport.
(Illustration: Aaro Designsystem)

Sedum roof, Augustenborg, Malmö.
(Photo: Christina Wikberger)

POINTS OF DEPARTURE FOR C/O CITY

The central point of departure for C/O City is the realization that the level of carbon dioxide in the atmosphere has increased from 280 ppm in the pre-industrial era to 400 ppm today. Emissions must be reduced to under 350 ppm and warming limited to 1.5–2 °C in order to avoid dangerous climate change. Loss of biodiversity is proceeding at a faster pace than ever before. Sixty per cent of the ecosystem services on which we depend are over-exploited or used without consideration for the long-term. Twenty-five per cent of protected natural areas are within 17 km of the world's rapidly growing cities. Rapid urbanization and densification are exacerbating the threats to our environment.

Biodiversity and functioning ecosystems are essential for sustainable cities and they can be used to meet a variety of important needs. Practical tools and methods for meeting these needs have significant potential and are attracting a lot of interest internationally.

Planetary Boundaries

There are now more than seven billion people on the planet, and we are exceeding the Earth's limited resources due to our lifestyles and consumption habits. We have to plan for human development on a resource-constrained planet. In 2009, Professor Johan Rockström et al., Stockholm Resilience Centre, published a report in Nature about planetary boundaries i.e. the biophysical processes that humanity is in danger of exceeding.

The science shows that these nine processes and systems regulate the stability and resilience of the Earth System – the interactions of land, ocean, atmosphere and life that together provide conditions upon which our societies depend. In addition there are threshold effects that we cannot predictable.

Four of nine planetary boundaries have now been crossed as a result of human activity, according to the international team of 18 researchers in the journal Science (16 January 2015). "Transgressing a boundary increases the risk that human activities could inadvertently drive the Earth System into a much less hospitable state, damaging efforts to reduce poverty and leading to a deterioration of human wellbeing in many parts of the world, including wealthy countries," says lead author, Professor Will Steffen, researcher at the Stockholm Resilience Centre and the Australian National University, Canberra.

1. Climate Change

By burning fossil fuels we release billions of tons of carbon dioxide per year into the atmosphere, which is the major cause of the enhanced greenhouse effect. The increase in average temperature has accelerated in the last 50 years. In that time the average temperature has risen by about 0.5 °C. and since the pre-industrial period it has risen by 0.8 °C. The UN Intergovernmental Panel on Climate Change (IPCC) estimates that we must remain within a 2 °C increase to avoid great hardships for humanity. To keep the temperature increase below that level, the amount of carbon dioxide in the atmosphere should not exceed 350–400 ppm (parts per million). Yet 400 ppm has now been reached (September 2016). There has not been such a high level for 800,000 years.

Methane and nitrous oxide also have a significant impact on the greenhouse effect, and their values are usually converted to CO_{2e} (CO_2 equivalents) to compare with carbon dioxide (CO_2). Carbon dioxide remains in the atmosphere for hundreds of years so the Earth will keep getting warmer even if we reduce our emissions. We have to ensure that concentrations of greenhouse gases in the atmosphere decrease rather than increase. Recent evidence suggests that the Earth, now passing 400 ppm CO_2 in the atmosphere, has already transgressed this planetary boundary and is approaching several Earth system thresholds. We have reached a point at which the loss of summer polar sea-ice is almost certainly irreversible.

2. Stratospheric ozone depletion (Thinning of the Ozone Layer)

The stratospheric ozone layer in the atmosphere is a protective shield against ultraviolet (UV) radiation from the sun. UV-radiation can cause skin cancer as well as damage to terrestrial and marine biological systems. The ozone layer in the atmosphere breaks down due to emissions of gases such as CFCs, nitrogen oxides and bromine. Fortunately, because of the actions taken as a result of the Montreal Protocol, we appear to be on a path that will enable us to stay within this boundary.

3. Increase in Atmospheric Aerosols

The concentration of aerosols, which impacts both climate and the health of many living organisms, is due to air pollution from both heated soot particles and cool particles, such as nitrates and sulphates. Aerosols play a critical role in cloud formation, in atmospheric circulation and they have a direct effect on climate. Strategies have to be developed to reduce these.

Flooding and the ensuing increased costs and day-to-day problems will be increasingly common.
(Source: Nynäshamn Municipality, 2005)

4. Ocean Acidification

Acidification of the oceans, caused by emissions from fossil fuels, worsens conditions for marine life. For instance coral reefs and shellfish are threatened. The combination of overfishing and eutrophication as well as warmer sea water worsens living conditions and reduces the oceans' capacity to store carbon dioxide. Compared to pre-industrial times, surface ocean acidity has increased by 30 %. Unlike most human impacts on the marine environment, which are local in scale, the ocean acidification boundary has ramifications for the whole planet. The links are crystal clear and provide strong arguments for quickly and decisively reducing carbon dioxide emissions, irrespective of the risks posed by a warmer and more unstable climate.

5. Global Freshwater Use

The freshwater cycle is strongly affected by climate change and its boundary is closely linked to the climate boundary, yet human pressure is now the dominant driving force determining the functioning and distribution of global freshwater systems. Agriculture is the largest consumer of water. Approximately 70 % of the fresh water use goes to irrigation. As a result of the over-exploitation of fresh water resources, about a quarter of the world's major rivers no longer reach the ocean parts of the year. Securing food for one person per year requires approximately 1,300 m^3 of water. A water boundary related to consumptive freshwater use and environmental flow requirements has been proposed to maintain the overall resilience of the Earth system and to avoid the risk of 'cascading' local and regional thresholds.

6. Chemical Pollution etcetera

Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials represent some of the key human-driven changes to the planetary environment. Toxic chemicals are added to many products including construction materials, furniture, clothing, skin care products, food packaging and food. Persistent organic compounds have caused dramatic reductions in bird populations and impaired reproduction and development in marine mammals. We need to reduce the concentration of undesirable chemical substances in our environment and try to achieve a non-toxic society.

7. Land system change

Land is converted for human use all over the planet. Forests, grasslands, wetlands and other vegetation types have primarily been converted to agricultural land. This land-use change is one driving force behind the significant reductions in biodiversity, and it also has impacts on water flows and on the biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements. Forests play a particularly important role in controlling the linked dynamics of land use and climate, and their preservation is the focus for the boundary for land system change.

8. Biodiversity loss and extinctions

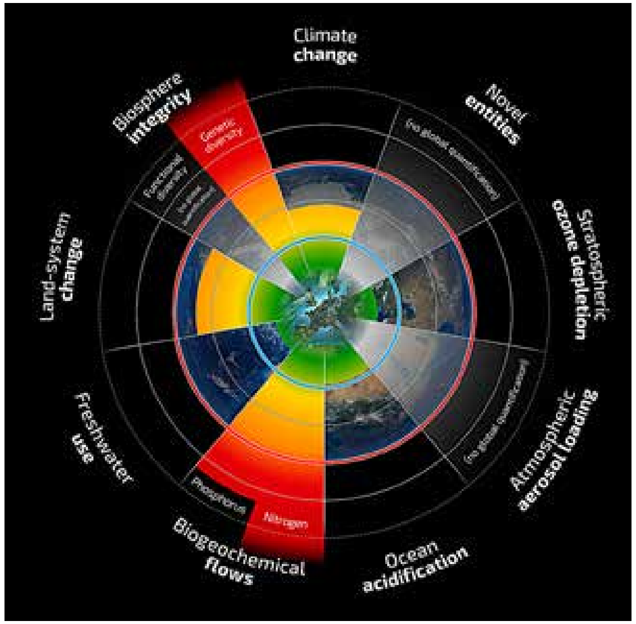
The Millennium Ecosystem Assessment of 2005 concluded that changes to ecosystems due to human activities had been more rapid in the past 50 years than at any time in human history, increasing the risks of abrupt and irreversible changes. We now realise that loss of biodiversity is not just about protecting individual species, but about threats to our food supply and about ensuring the greatest possible resistance against disturbances such as climate change. The current rate of extinction of species is believed to be between a hundred and a thousand times greater than the natural rate. We have to protect the integrity of living systems (the biosphere), enhance habitat and improve connectivity between ecosystems.

9. Nitrogen and phosphorus flows to the biosphere and oceans

The largest flows of nitrogen and phosphorus come from fertilisers in agriculture, but nitrogen oxides from traffic also contribute. These flows result in eutrophication, algal blooms and oxygen-depleted sea bottoms caused by biological breakdown processes.

In future, input of phosphorus in agriculture will be a major problem. Modern agriculture uses a lot of artificial fertilisers and leaching of phosphorus and nitrogen from fields is considerable. Phosphorus, like oil, is a fossil resource. As for "peak oil" there is a concern about "peak phosphorus".

A significant fraction of the applied nitrogen and phosphorus makes its way to the sea, and can push marine and aquatic systems across ecological thresholds. One example of this effect at a regional level is the decline in shrimp catch in the Gulf of Mexico's "dead zone" caused by fertilizer transported in rivers from the US Midwest.



Planetary boundaries of nine global processes. The inner green circle represents the relatively safe operating space and the red bars represent the current position for each variable. There are no defined boundaries for chemical pollutants and aerosols (air particles), so the situation regarding them is uncertain.

(Source: Steffen et al. Planetary Boundaries. Guiding human development on a changing planet, Science, 16 january 2015. Design: Globaia)

ECOSYSTEM SERVICES – an Introduction

"Ecosystem services" is a name for all the good things we get from nature. The planet's ecosystems supply us with goods and services. They provide us with food, water and materials, they clean air and purify water, bind the soil, decompose dead matter and pollinate our crops. Ecosystem services are often delivered through interactions between people and nature, and they directly or indirectly affect our welfare. We need ecosystems for our survival and we must use nature's services in a way that does not jeopardise the welfare of future generations. We are all part of the global ecosystem.

Historically, we have tended to take nature for granted. Today human activities affect such large swathes of the planet that our and other species' survival is threatened, so we have to reconsider our approach to ecosystem services.

Ecosystem services are usually divided into four categories: supporting, provisioning, regulating, and cultural services.

The supporting services are fundamental processes that make life on Earth possible.
• The sun, which radiates energy to the earth, which makes photosynthesis and plant growth possible.
• The soil, decomposition and the circulation of nutrients which are the foundation for life.
• The water and its cycles between the atmosphere and Earth's surface, which are also prerequisites for life.
• The air, the atmosphere and its composition affect climate and the possibility of life.
• Biodiversity, the fabric of life on Earth in the form of micro-organisms, plants and animals.

An example of a regulating ecosystem service is when bees pollinate plants, which is required in 75–90 % of the cases where plants become human food. Where there are no insects to do the work, the work is done manually, which is both time-consuming and laborious.

The provisioning services make it possible for us to live on our planet.
• Water: drinking water and access to water.
• Food: cultivated crops, edible wild plants, livestock, poultry, game, fish, shellfish and algae in lakes and oceans.
• Trees for timber, lumber and biomass.
• Natural fibres such as flax, hemp, cotton and silk.
• Herbs for natural medicines and cosmetics.
• Flowers.
• Genetic resources.

The regulating services provide the right conditions for life.
• Air purification and air quality.
• Water purification and water regulation.
• Erosion control and protection against natural disasters.
• Regulation of the local and global climate.
• Soil fertility, decomposing organic waste.
• Dilution, decomposition and recirculation of pollutants.
• Noise reduction.
• Pest and disease control.
• Pollination of plants.
• Protection and maintenance of habitats and gene pools.

The cultural services contribute to our well-being.
• Recreation and eco-tourism: nature as a source of peace and relaxation.
• Spiritual values: nature as a source of inspiration in the search for life's meaning.
• Aesthetic values: enjoyment of the beauty of nature.
• Symbolic values: in arts, culture and heritage.
• Ecological insight: understanding how everything is connected and that we are a part of it all.

Ecosystem services are visible ways in which nature provides for "free", but if they are destroyed we will face major problems, sacrifices and costs. However, putting monetary value on ecosystem services is problematic, e.g. how much is clean air worth?

ECOSYSTEM SERVICES		
Supporting services (Make life on the planet possible) SUN EARTH WATER AIR (energy) (nutrition) (ecological cycles) (the atmosphere)		
Provisioning services	**Regulating services**	**Cultural services**
CROPS (provide food)	WETLANDS (clean water)	NATURE (recreation)
LUMBER (provide materials)	BEES AND BIRDS (pollination, dispersing seeds)	ANIMALS AND PLANTS (ecological insight)
FIBERS (can be fabric)	DECOMPOSITION (makes soil fertile)	CULTURAL LANDSCAPE (beauty)
HERBS (spices, medicines)	FORESTS (produce oxygen)	OLDER BUILDINGS (cultural history)

Ecosystem services are usually divided into four categories: the supportive services that make life on Earth possible, the provisioning services that give us what we need to survive, the regulatory services that take care of the ecological cycles, and the cultural services that make life worth living.

Ecosystem services can, according to TEEB (The Economics of Ecosystems and Biodiversity), be evaluated in the following way:

1. Describe the ecosystem service carefully.
2. Do a qualitative valuation.
3. Do a quantitative valuation.
4. Ultimately, try to arrive at a monetary value.

But doing this is not easy. Ecosystems fulfil several functions simultaneously and capturing the value of multi-functionality is difficult. Furthermore it is hard to measure the many diverse impacts of ecosystem services, so it is likely that any calculations are under-estimates. However, if we make visible all the ecosystem services that an area provides, we can make more informed decisions. The following are some methods of monetary valuation: direct market prices, opportunity costs according to market prices, the surrogate market, willingness to pay, valuation by participatory methods, and benefit transfer.

BIODIVERSITY

In simple terms biodiversity is variation of species, their genetic variation and the variation of landscape types. Preservation of biodiversity not only means protection of species, but also protection of the genetic diversity within species. Variations within species are necessary for life to continue to evolve and adapt to new conditions. Maintenance of biodiversity requires the preservation of a wide diversity of habitats and natural processes. Domesticated plant and animal species are also an important part of biodiversity, and our future food supply is dependent on how we use them.

Some habitats, such as rainforests and deciduous forests, are especially important. These unique environments, created over thousands of years, support a large percentage of the world's species and have the resources to allow great diversity. Species in these areas have unique genetic and biological adaptations that are worthy of protection, both for ourselves and for future generations.

Genetic resources are important everywhere, for instance for the development of new crops and medicine. We really don't know what happens when important species disappear so we should apply the precautionary principle.

RESILIENCE

Resilience is the capacity of an ecosystem – whether a forest, city or an economy – to survive and adapt to changes. It has to do with resistance, adaptability and the ability to restructure in the event of significant disturbance. An ecosystem's resilience is influenced by biodiversity, which allows for a distribution of risks and a greater possibility for recovering and restructuring.

Where there is little diversity and low resilience, a small change in a sensitive system can lead to a sudden and unexpected ecological collapse. Such events can be irreversible.

PROVISIONING SERVICES


FORESTS PROVIDE TIMBER


AGRICULTURE PROVIDES FOOD


FIBRE PROVIDES CLOTH

REGULATING SERVICES


DECAY PROVIDES TOPSOIL


WETLANDS CLEAN WATER


TREES PRODUCE OXYGEN

CULTURAL SERVICES


RECREATION


BEAUTY IN LANDSCAPES


CULTURAL HISTORY

Greater biodiversity increases resilience and therefore improves the chances of coping with climate change and other ecological stresses, which in turn enables long-term sustainable provision of ecosystem services essential for human welfare. In the past, the term "ecological balance" was used, but this was misleading as all ecosystems change over time. Therefore, the concept of ecological resilience is currently preferred.

Ecological resilience has to do with the realization that people and nature are so interconnected that they should be regarded as one interwoven social-ecological system. This approach is reminiscent of the concept of human ecology ie the study of the relationship between people and their natural, social and build environments. In our globalized society, there are almost no ecosystems that have not been affected by people, and no people who are not wholly dependent on the services that ecosystems provide. The problem is that many seem to have forgotten that our economies and societies are fundamentally interwoven with the planet and its life-sustaining ecosystem services.

It is important to recognise that ecosystem services constitute the basis for human welfare and social and economic development. If ecosystems fail, human livelihood is jeopardized. We must therefore protect and preserve all ecological processes if we are to have food, clean water and clean air. It is high time to reconnect with nature and to start managing natural capital in a sustainable way.

ENVIRONMENTAL THREATS

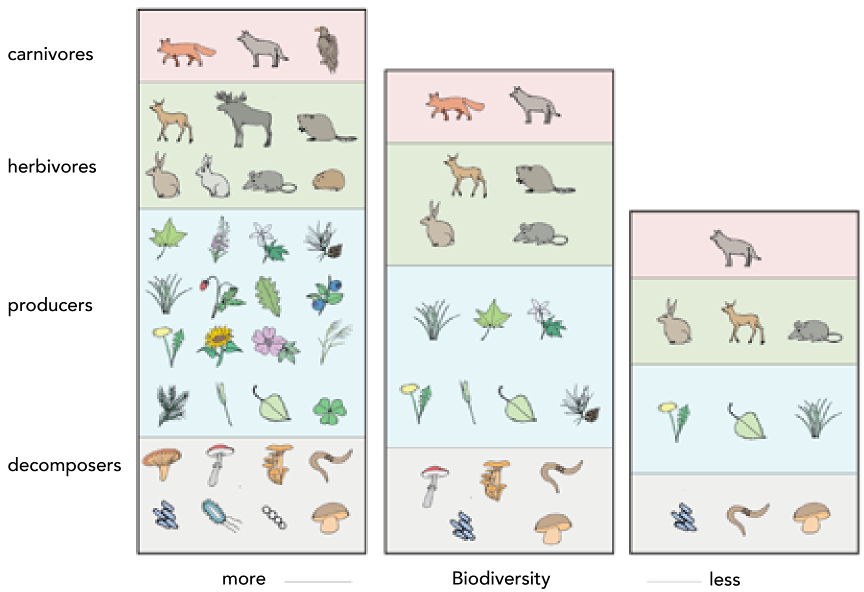
What threatens biodiversity? Biodiversity is not just found in remote places. On the contrary biodiversity exists in all the different environments created by people, such as farmland, plantations, parks, our homes and gardens. Preserving biodiversity is therefore as much about protecting ancient native breeds of domestic animals as about protecting rare beetles. Among the greatest threats to biodiversity are habitat destruction and climate change, which are both the result of human activity.

The natural habitats of many organisms are shrinking due to human activity. In Sweden, the most serious threats to biodiversity, at least in the short-term, are physical intrusions into natural areas, such as forestry, agriculture, hydroelectric power plants and roads. Hunting and the release of environmental toxins can also have a big impact. The more species that disappear from an ecosystem, the greater the risk that it cannot deliver ecosystem services.

SUSTAINABLE COMMUNITY DEVELOPMENT

Resilience thinking involves building in flexibility and adaptability instead of focusing on short-term efficiency. The availability of cheap fossil energy and the over-exploitation of resources since World War II have led to a consumer society that is pushing humanity dangerously close to the planet's limits, so much so that abrupt changes in climate and the natural environment cannot be ruled out. Resource constraints, economic instability, inequality and environmental degradation are clear signals that business as usual cannot continue.

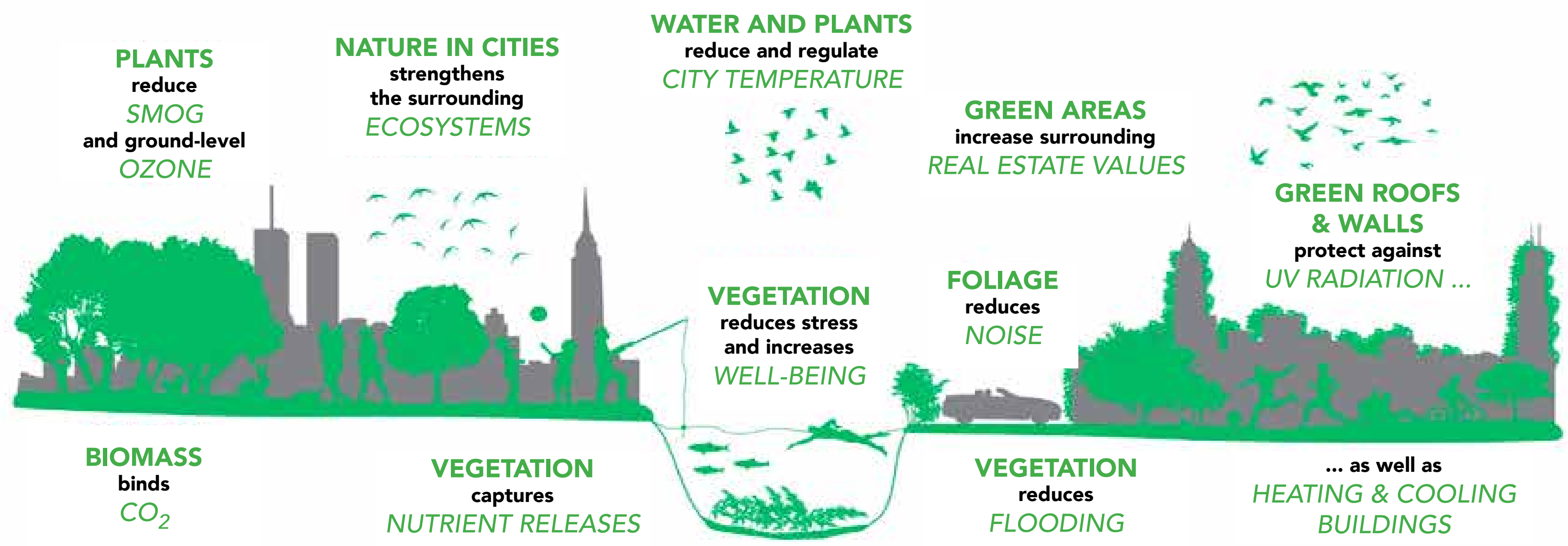
The big question is how we can become wise stewards of the planet, ensuring our lifestyles are compatible with sustainable use of the Earth's ecosystem. Change is already underway in the form of transition towns (a global network of people acting locally to meet the challenges of global warming and climate change), green cities, agro-ecological farming, renewable energy, ecosystem-based fisheries, energy-efficient buildings etc. However, many economic and technical solutions are still characterized by ecological illiteracy. They are too linear and focused on single problems in isolation. The challenge we face is to change lifestyles and current patterns of community development in order to reconnect society with the biosphere and to stay within planetary boundaries.



Food chains consist of decomposers, producers, herbivores and carnivores. Biodiversity is highly dependent on the conditions for species at the bottom. The fewer the species lower down in the food chain, the fewer the species higher up.

(Illustration: Vera Hint Kindgren)

URBAN ECOSYSTEM SERVICES



(Illustration: C/O City)

Ecosystem services is a concept that draws attention to the dependence of people on nature. The term ecosystem services is perhaps new, but the concept is not. Municipalities are used to working with, for example, stormwater management and green spaces, but what is new and sometimes challenging, is working with the interactions between such initiatives. Through early cooperation in the planning process between different disciplines and stakeholders, green and blue structures can both help to solve challenges and contribute to creating healthy environments.

A city without ecosystem services is neither attractive nor alive. Creating, protecting and developing ecosystem services in urban areas can reduce ecological footprints while enhancing resilience and improving health and quality of life. By incorporating green spaces with plants and water courses, we can establish urban ecosystem services. Green-blue structures, the ground they rest on, and the animals, birds and insects that live there will provide us with the ecosystem services we need.

Greenery can help to regulate microclimates, clean the air and reduce noise from traffic, at the same time as providing places for recreation with exposure to nature. Greenery can be placed between buildings, on roofs or walls, or as trees along streets. Careful choice of plants, insect and bird feeders as well as proximity between green spaces can provide good habitats for pollinating insects and birds that disperse seeds. Permeable land, ponds and wetlands can take care of rainwater by levelling off the flow. Children who grow up in such environments are healthier and have a greater appreciation for nature.

Food: The ecosystem provides us with opportunities to grow food. Food comes primarily from agricultural ecosystems, but also from urban gardens.
Drinking water: The ecosystem plays an important role in supplying cities with drinking water by taking care of water flow, storage and purification. Vegetation and forests affect water supply.
Species habitat: A habitat is a living environment for plants, animals or other organisms which includes the resources those species need to survive, for example food, water and protection. Every ecosystem provides habitats that can be critical for a species' lifecycle. Some habitats provide for an especially large number of species so they are more genetically diverse than others (so-called "hot spots").
Microclimate: Trees and green areas in cities lower the temperature, and forests affect precipitation and local and regional water supply. Trees can also shade streets and public squares.

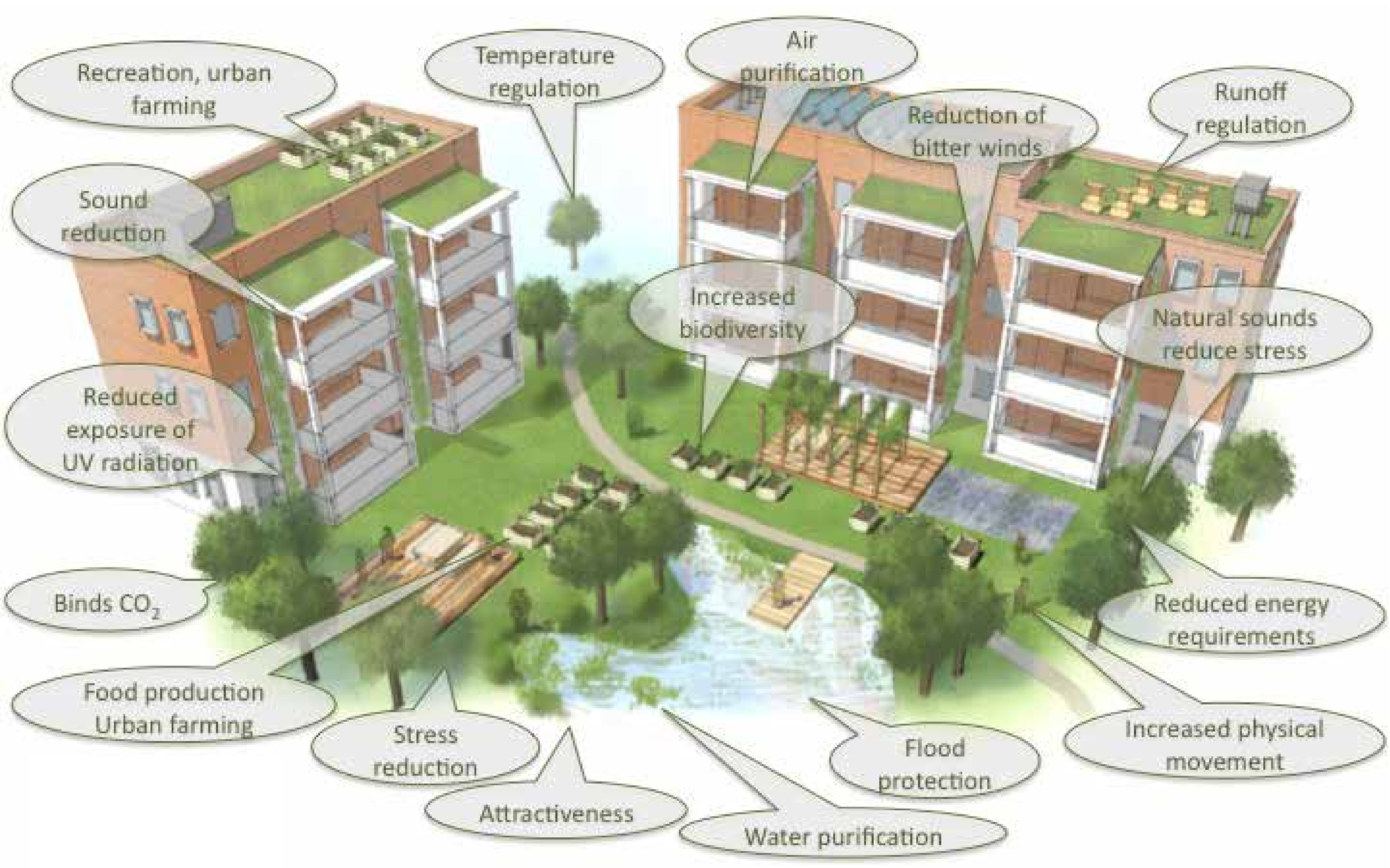
Local air quality: Trees and other vegetation have a significant role in regulating air quality by absorbing air pollutants. Deciduous trees are efficient at cleaning air. In northern latitudes, coniferous trees can contribute to purifying air even during the winter.
Noise reduction: Noise in cities affects health, the ability of children to learn, and animal life. Trees and vegetation can reduce noise.
Binding of carbon and carbon dioxide: Ecosystems regulate global climate by storing greenhouse gases. Storage of carbon takes place when trees and other plants absorb carbon dioxide from the atmosphere and bind it in their tissues. Trees absorb carbon dioxide and give off oxygen.
Buffer for extreme weather events: Ecosystems have the ability to protect or reduce damage from extreme weather and natural catastrophes, for example downpours and floods.
Erosion protection and preservation of fertile soil: Plants can hold soil in place on slopes. Root systems bind the soil, while leaves and branches protect the soil from rain and reduce erosion.
Wastewater treatment and reduction of stormwater flows: Wetlands filter stormwater and releases. Through the biological activity of microorganisms in soils, sewage is biodegraded. Pathogens are removed and levels of nutrients and pollutants are reduced. Green spaces, both on the ground and on roofs, can absorb stormwater locally, which in turn reduces the load on water treatment plants during heavy precipitation.
Pollination: Insects and the wind pollinate plants that develop fruit, vegetables and seeds. Pollination is primarily carried out by insects, but birds and bats also play important roles in pollination and seed dispersal.
Biological pest control: Ecosystems are important for regulating attacks from pests and vector-borne diseases which attack plants, animals and people. Birds, bats, flies, wasps, frogs and fungi act as natural pest controllers.
Increased value of real estate: Research shows that housing in areas with trees and/or proximity to green areas have higher market values than in other areas.
Tourism: Ecosystems and biodiversity play a major role in tourism, which is important for many local economies.
Education: Outdoor play positively affects cognitive development and facilitates learning about nature and the environment.
Recreation, mental and physical health: Walking, sports and other physical activities provide exercise and relaxation. Green structures in cities play an important role in creating incentives for physical activity and reducing stress. They are essential for mental health and important for children's development.

For green spaces to be used regularly and to provide the right conditions for active lives, they must be located close to homes or work, and be accessible by foot. The longer the distances from home or work to green spaces and parks, the fewer and the shorter the visits will be. Research has shown that 300 meters without roads or barriers is the limit for how far people are willing to walk. A good green space promotes children's psychological, social, physical and motor development. Spending a lot of time in green areas positively affects the ability of children to concentrate, they spend more time doing physical activity and are healthier. There are studies that show that children at pre-schools with good access to nature have better motor skills and concentration, fewer sick days and are healthier than children at pre-schools with poor access to nature.

Example of ecosystem services that can be relevant in an urban environment. (Illustration: WSP)

An example of good urban planning, with green spaces, water spaces, sitting areas, and bicycle and jogging tracks.
(Source: Run Wild Marathon, Alberta, Canada. Flickr, photo: Sangudo)

Even in existing urban environments many ecosystem services can be provided, as in Augustenborg, Malmö, where an area built up in the 1960's was given functional and beautiful surface water management. (Photo: Varis Bokalders)



There is demand for multi-functional greenery in urban environments where space is often a limiting factor. By encouraging greenery and aquatic environments that provide multiple functions and enhance ecosystem services, the values of urban areas can be increased. (Illustration: Magnus Petersson)

THE BIOTOPE AREA FACTOR (BAF) – Introduction and Background

The Biotope Area Factor (BAF) was developed in the 1990s in Berlin, Germany, as an ecological standard to support green urban development. The method was introduced in Sweden in conjunction with the Bo01 international housing exhibition in Malmö. The Biotope Area Factor has since been developed further in the planning of the Stockholm Royal Seaport (2014) as "a climate-adapted and green outdoor environment." In the planning process the urban design principle "let nature do the work" emerged, which increased attention on ecosystem services. The Biotope Area Factor for Norra Djurgården, Stockholm Royal Seaport, was developed to identify ecosystem services and to encourage the strengthening of local ecosystems and creation of climate-adapted courtyards with high social values. Planners, architects and developers received a practical planning tool adapted to their way of working, which facilitated and inspired planning and design with ecosystem services in focus.

Work with ecosystem services in the Stockholm Royal Seaport has attracted great interest within Sweden and from abroad. The Biotope Area Factor is being used in more and more projects. For city development, the tool enables planners to focus on creating multi-functional spaces in which ecosystem services such as biodiversity, stormwater management and social values are taken into account.

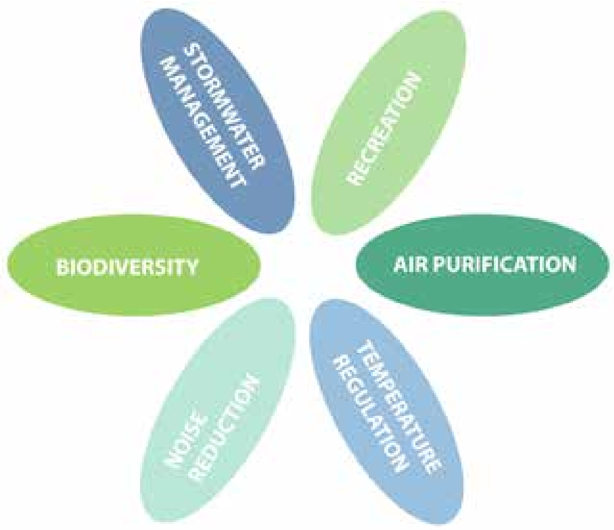
The Biotope Area Factor is calculated as a ratio between "eco-efficient" areas and total land surface. The eco-efficient areas comprise the total green and blue areas designed according to certain predefined requirements. The tool is versatile and allows for measurement, quantification, monitoring as well as comparison of different urban environments.

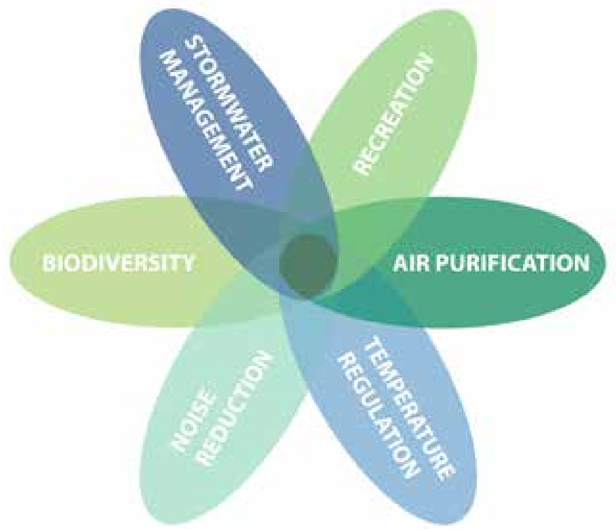
Type of surface	Factor
Impervious surface impermeable to water and air, no plant establishment. (concrete, asphalt, impenetrable surface)	0,0
Partially impervious surface permeable to water and air, without plant establishment. (paving stones, sand, gravel)	0,3
Half open surfaces permeable to water and air, some plant establishment. (gravel with grass, wooden deck, grass reinforcement)	0,5
Plant surfaces without contact with the underlying ground, upper decks (over underground cellars or garages) with less than an 80 cm earth layer	0,5
Plant surfaces having no contact with the underlying ground, more than 80 cm earth layer	0,7
Plant surfaces with ground contact, vegetation with ground contact, accessible for development of flora and fauna	1,0
Rainwater infltration per m2 roof area, precipitation infiltrates and regenerates groundwater, infiltration over surfaces with existing vegetation	0,2
Vertical greenery up to 10 m high, greenery that covers inner and outer walls without windows, the actual height, up to 10 m, is taken into consideration	0,5
Green roofs, extensive and dense plant cover on a roof surface	0,7

An example of a Biotope Area Factor (BAF) report for a project in Berlin.

$$\text{BAF} = \frac{\textbf{ecologically effective areas (m}^2\textbf{)}}{\textbf{total land area (m}^2\textbf{)}}$$

The Biotope Area Factor (BAF) is the ratio of areas of a site that have either a positive effect on ecosystems or an effect on the development of the biotope of a site, in relation to the entire area of the site being developed.





Biotope Area Factor in the Stockholm Royal Seaport includes greenery that fulfills several functions.
(Illustration: Daniel Larsson, WSP)

The Biotope Area Factor (BAF) for Urban Areas

The growing interest in work with ecosystem services in urban planning gave rise to the C/O City project, initiated by the city of Stockholm and financed by Vinnova. A sub-project within C/O City has been to develop a Biotope Area Factor for the city's public land in line with the requirements formulated in the sustainability programme for the Stockholm Royal Seaport.

A Biotope Area Factor for public land has been developed by the city of Stockholm, the city of Malmö and WSP. The tool should be considered as a test version with potential for further development. The tool builds on the Biotope Area Factor for city blocks and has the same purpose - to create multi-functional areas that work well from an ecosystem service perspective. The tool's scale of application and specifications are different from the Biotope Area Factor for city blocks. The model is intended for use at different levels, from masterplans, programmes and structural plans down to more detailed plans. However, the tool is not yet precise enough to be applied to planning parks, public squares and similar smaller areas.

In the C/O City project, a number of ecosystem services have been selected and developed within the Biotope Area Factor for public land: biodiversity, pollination, climate adaptation (including micro-climate regulation and stormwater management), noise reduction and cultural ecosystem services (recreation, health, social relations etc.). Pollination and noise reduction are new additions to the tool.

In the planned area Stora Sjöfallet in the Stockholm Royal Seaport the developers have used the Biotope Area Factor.
(Illustration: NCC Bostad via Brunnberg & Forshed Architects Office)

As in the model for the Biotope Area Factor for city blocks, the amount of "eco-efficient area" is compared to the total area of public land. The difference is that the Biotope Area Factor for public land is focused more on the qualities and functions of an area and less on their size and exact content. Therefore, the concepts of "areas" and "qualities" are used here to define both whole and partial areas. Together, the Biotope Area Factor for city blocks and for public land make up the total biotope area factor for the city district or the planning area.

Insect hotel and fruit-bearing tree. (Photo: Varis Bokalders)

Oak. (Photo: Christina Wikberger)

	SURFACE	FACTOR	NUMBER	AREA m²	TOTAL
	Sub-factors greenery				
BKS	unsupported ground greenery	2.0	-	0	0
BKS	plant bed (≥ 800 mm)	1.2	-	75	90
BKS	plant bed (200–800 mm)	0.2	-	675	135
BKS	green roof (> 300 mm)	0.4	-	0	0
BKS	green roof (50–300 mm)	0.1	-	500	50
BKS	greenery on walls	0.4	-	500	200
BKS	balcony boxes	0.3	-	0	0
	Supplementary factors greenery/biodiversity				
B	butterfly restaurants	1.0	-	100	100
B	natural species selection	0.5	-	50	25
B	diversity in the field layer	0.7	-	0	0
B	diversity on thin sedum roofs	0.1	-	0	0
B	integrated balcony boxes with climbing plants	0.3	-	0	0
B	bushes, general	0.2	-	300	60
B	berry bushes	0.4	-	50	20
B	large trees (trunk > 30 cm)	2.4	-	-	0
B	medium large trees (trunk 20–30 cm)	1.5	3	125	188
B	small trees (trunk 16–20 cm)	1.0	5	125	125
B	oak	3.0	3	75	225
B	fruit trees	0.4	5	125	50
B	beetle feeders	2.0	2	50	100
B	bird feeders	2.0	4	100	200
B	fauna depots	2.0	-	50	100
	Supplementary factors greenery/recreation and social value				
S	grass areas usable for ball games and playing	1.2	-	75	100
S	gardening areas in yards	0.5	-	-	0
S	balconies and terraces prepared for growing	0.5	-	0	0
S	shared roof terraces	0.2	-	0	0
S	visible green roofs	0.1	-	500	50
S	floral arrangements	0.2	-	200	40
S	experiential value of bushes	0.1	-	300	30
S	berry bushes with edible fruit, etc.	0.2	-	50	10
S	trees, experiential value	0.5	8	200	100
S	fruit trees and blooming trees	0.2	5	125	25
S	pergolas, paths surrounded by leaves and other greenery	0.3	-	160	48
S	bird feeders, experiential value	0.2	4	100	20
	Supplementary factors greenery/climate - heat islands				
K	trees with leafy shade over play areas etc.	0.5	2	50	25
K	pergolas, green corridors etc = shade from leaf cover	0.5	-	160	80
K	green roofs, ground greenery that regulate temperature	0.1	-	500	50

The table continues on page 16

The table continues from page 15

	SURFACE	FACTOR	NUMBER	AREA m²	TOTAL
	Sub-factors water				
BKS	water surface, permanent	1.0	-	50	50
BKS	open hard surfaces that allow water to get through	0.3	-	25	8
KS	gravel and sand	0.2	-	986	197
KS	concrete slabs with joints	0.05	-	100	5
KS	impermeable surfaces	0	-	0	0
	Supplementary factors water/biodiversity				
B	biologically accessible permanent water	4.0	-	50	200
B	dry areas with plants that temporarily fill with rainwater	2.0	-	0	0
B	delay of rainwater in ponds etc.	0.2	-	1,000	200
B	delay of rainwater in underground percolation systems	0.1	-	500	50
B	runoff from impermeable surfaces to surfaces with plants	0.1	-	-	0
	Supplementary factors water/recreational and social values				
S	water surfaces	1.0	-	50	50
S	biologically accessible water - experiential value	1.0	-	50	50
S	fountains, circulation systems, etc.	0.3	1	25	8
	Supplementary factors water/climate - heat islands				
K	water collection during dry periods	0.5	-	50	25
K	collected rainwater for watering - climate impact	0.05	-	500	25
K	green roofs, ground greenery - evening out of temp.	0.3	1	25	8
	Total (eco-efficient area)				***3,120***
	average factor				
	total land area			***5,200***	
	ACHIEVED FACTOR				**0.60**

BALANCE SHEET	NUMBER OF FACTORS
B = biodiversity	**18**
K = climate adaptation	**14**
S = social value	**19**

The table is an example of what the Biotope Area Factor for a city block looks like in the Stockholm Royal Seaport development.

Examples of grass reinforcement that allows water through. Left: Reused polyethene plastic. Right: Ground concrete.

Special bat nest boxes.

Seabirds thrive in ponds and wetlands.

Pond with salamanders. (Photo: Johan Pontén)

Beautiful stormwater management. (Photo: Christina Wikberger)

Bo01 area in Malmö. (Photo: Varis Bokalders)

Selection of Urban Ecosystem Services

In the C/O City project, a number of urban ecosystem services were selected for inclusion in the Biotope Area Factor for public land: biodiversity, pollination, microclimate regulation, stormwater management, noise reduction, culture, recreation and health.

BIODIVERSITY

Biodiversity is a precondition for almost all other ecosystem services and creates resilience in ecosystems. Resilience is the ability of an ecosystem to withstand disturbances and to adapt to changes. In resilient ecosystems there is room for a variety of species, functions and processes. It is difficult to determine a critical limit that indicates when an ecosystem is sufficiently resilient – each case must be assessed according to its specific context. Generally larger areas can contain more habitats (biotopes), and can therefore offer a higher degree of variation in species, functions and processes. Small, more isolated areas with little or no variation are generally more sensitive to disturbances. This general rule also applies to urban environments.

In planning for biodiversity the focus is on preservation and enhancement of ecosystems through new construction or maintenance of critical habitats, core ecological areas, pathway zones etc. Habitats may separately or together contain a great variety of species, several important functions and ecological processes (core values). Also important is preserving or supplementing habitats for important species or groups of species, such as umbrella species and functional groups, and securing pathway and buffer zones. Through conscious choice of plants, good spatial arrangement and consideration of the surrounding environment, the conditions for resilient ecosystems can be improved.

POLLINATION

"Urban farming" is a growing movement. Bees, bumblebees and butterflies pollinate flowers and crops, and urban farms contribute to recreational and aesthetic values for city residents. At the same there are indications that cities can supply the surrounding landscape with pollinators so that agriculture is supported. Pollination is strongly linked to biodiversity and vice versa.

The focus is on the preservation and creation of areas with resources for pollinators, and on the group of species that contribute most to pollination i.e. bees (bumblebees and honeybees). Bees need places to live and areas with food throughout the months during which they are active i.e. from early spring to late autumn. Food resources are plants that are rich in nectar (food for adult bees) and pollen (food for larvae), for example clover, willow and herbs. The choice of plants should ensure the availability of food resources throughout the active season in order to increase the bees' chances of survival through the winter.

STORMWATER AND MICRO-CLIMATE

As the proportion of impermeable surfaces increases, urban environments tend to become warmer and stormwater becomes more of a problem. Room must be found for ecosystem services that reduce the risks of costly and devastating events such as flooding and heat waves hazardous to health. Green areas absorb heat and can cool surrounding buildings by several degrees during both day and night. Plants that provide shade efficiently reduce the stress from heat experienced by people in urban environments during periods of hot weather. Open water areas have both a cooling and humidity-enhancing effect. Existing or specially constructed stormwater management areas such as wetlands, green roofs and plant beds can receive, absorb and clean stormwater and thus reduce the risk of flooding and overloading of stormwater systems.

The focus is on preserving and creating green and blue areas with high cooling and humidifying effects. Green areas with a high proportion of trees and high soil moisture cool the surrounding environment more than open lawns with low soil moisture. Placement of vegetation in sunny, heat-exposed and poorly-ventilated areas is prioritized. Several layers of plants increase the vegetation per surface unit, which improves the cooling effect. Streetscapes must be designed in ways that allow room for greenery without risking an accumulation of air pollutants. Green walls and low-growing vegetation can be used to achieve cooling and shade effects in cramped environments.

NOISE REDUCTION

Noise is a common phenomenon in cities. Greenery can muffle and absorb sound. Soft, green areas such as shelter belts, street parks, plant screens and green walls and roofs reduce both actual noise and the perception of noise.

In order to achieve the best noise reduction or absorbing effect, the soft green areas must be placed at a suitable distance from the source of the noise. Greenery in quiet environments cannot be included in Biotope Area Factor calculations. During the winter, a noise reduction effect is achieved with evergreen plants. There must be unconditional compliance with noise guidelines.

CULTURE, RECREATION AND HEALTH

In dense urban environments, areas must be put to several different uses, combining activities in both time and space. There must be experience-rich and busy areas as well as peaceful and quiet places.

Green environments offer relaxation and recovery which are essential for good health. Visits to and activities in natural and park environments reduce stress and positively affect blood pressure, ability to concentrate and mental processes. Proximity to nature for inspiration, relaxation and recreation makes us healthier and gives us a more positive image of our surroundings. A green-blue city district is an attractive city district.

It is important to be close to green areas. Everyone should have access to an attractive green area within 300 meters of their residence for daily outdoor visits. An acceptable distance to larger natural areas is one kilometre. Values and functions of green areas can be described as park characteristics or sociotopes.

Water and greenery in one of the courtyards in the Bo01area of Malmö.

Green Areas

- Green areas and green routes, e.g. parks, gardens, allotments, cemeteries and green paths.
- Greenery in impermeable areas, e.g. trees and plant beds in street areas, town squares, parking lots and playgrounds.
- Greenery on buildings and boundaries, e.g. green roofs, wildlife passages, green walls, wire greenery, greenery on fences and 3-D greenery.

Blue Areas

- Water areas and water courses, e.g. seas, lakes, bas, natural ponds and canals, streams and ditches.
- Green-blue areas, for example wetlands, broad-leaved wetland forests, moist deciduous forests, flooded fields and beach meadows.
- Areas and constructions with proximity to water, e.g. beaches, docks, stormwater gutters and sunken rain gardens.

[B] Biodiversity

- Preserved important biotope, dispersal corridor etc.
- Other preserved nature
- New establishment that support the ecosystem
- Important micro-habitats
- Managament plan

[P] Pollination

- Pollinator-supporting surface
- Pollinator-node
- Pollinator-important objects

[C] Climate adaptation

- Shade from single trees
- Shade from green constructions
- High-cooling surface
- Low-cooling surface
- Preserved surface with existing stormwater management function
- Preserved surface with potential for stormwater management function
- Constructed surfaces with infiltration, purification and retention of stormwater
- Surface for temporary flooding at extreme precipitation events
- Rainwater storage in irrigation constructions
- Trees in constructions for stormwater managament

[N] Noise reduction

- Road shelter belt > 30 m wide
- Road shelter belt 15-30 m wide
- Noise absorbing/reducing surface

[C] Culture, recreation & health

- Wilderness, diversity and intactness
- A sense of forest
- Open activity-surface
- Nature play
- Green oasis
- Large, sociotope-rich park
- New established, biodiverse area
- Sereneness
- Flower-rich surface
- Large, old tree
- Green pathways
- Green culture
- Water contact
- Bathing and water play
- Public participation

Areas and Qualities

In total there are six classes of area in the Biotope Area Factor for public land. For each ecosystem service an area can have a number of qualities. There is no limits on the number of qualities an area can have. The more qualities the greater the number of functions an area is fulfilling.

$$\text{BAF} = \frac{\text{ecologically effective area (m}^2\text{)}}{\text{area of the public land}}$$

Method Development

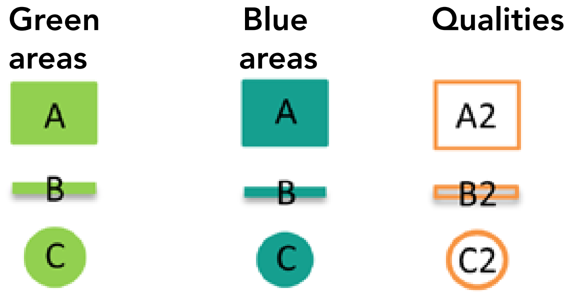
The Biotope Area Factor for public land is an Excel-based tool. As surface areas and qualities are entered, the model automatically calculates points and the overall result.

Surface areas are entered directly into the tool without a multiplication factor. The ratio between area and points is 1:1 (100 m^2 equals 100 points). The area of a surface can be calculated in three different ways: A, B and C. For method A the actual area is measured, for example an entire park. Method B is used for line-shaped, narrow objects, such as creeks where the area is obtained by multiplying the length by a known width, or a standard width if the width is unknown. Method C is used for point areas or areas of an unknown size where standard areas are used instead, for example for individual trees. There are guidelines for how the different areas must and can be calculated.

The qualities of an area are defined from an ecosystem service perspective. For example a park may contain areas with a high cooling effect (a quality under microclimate regulation) and cultivation (a quality under culture, recreation and health) and the park may be a soft green space adjacent to a noise source (a quality under noise). Qualities are calculated according to A2, B2 and C2. An area may have several qualities and therefore be included in the calculations entirely or partially several times. The qualities are weighted with a multiplier which automatically results in factor points. For example: a quality that has an area of 100 m^2 and that is multiplied by a factor of three results in 300 points.

Points add up to a grand total (area + qualities) which is then divided by the area of the public land, to give the Biotope Area Factor. In the future, the weighting of qualities will be further refined.

(Illustrations: Daniel Larsson, WSP and Felicia Sjösten, city of Stockholm)



A are areas such as lawns and ponds.
B are line-shaped areas such as hedges and creeks.
C are point-shaped areas such as trees and fountains.

Ecosystem Services in Urban Planning – a Guide

The guide presents tools and methods for integrating ecosystem services into urban planning, by developing work processes for dealing with green and blue structures. Even inside cities we are still completely dependent on nature, to provide us with food, clean water, oxygen, and the right temperature. If we are going to continue to live in cities and to feel good, we need to have functioning ecosystems within cities as well as nature surrounding cities. The guide was developed to support all stakeholders involved in urban planning in realising the potential of ecosystem services.

Masterplan

Since most ecosystem services are dependent on connections between areas and habitats, it is important that planning in municipalities and between regions is coordinated. Preserving and restoring ecosystem services in urban areas can reduce the negative ecological impact of cities while strengthening resilience, and the health and quality of life for residents. On this general level it is important to identify and map the following ecological functions:

- Biodiversity and pathways,
- The water cycle,
- Recreation and experience values,
- Food supply, and
- The need for green and blue structures in densely populated urban environments

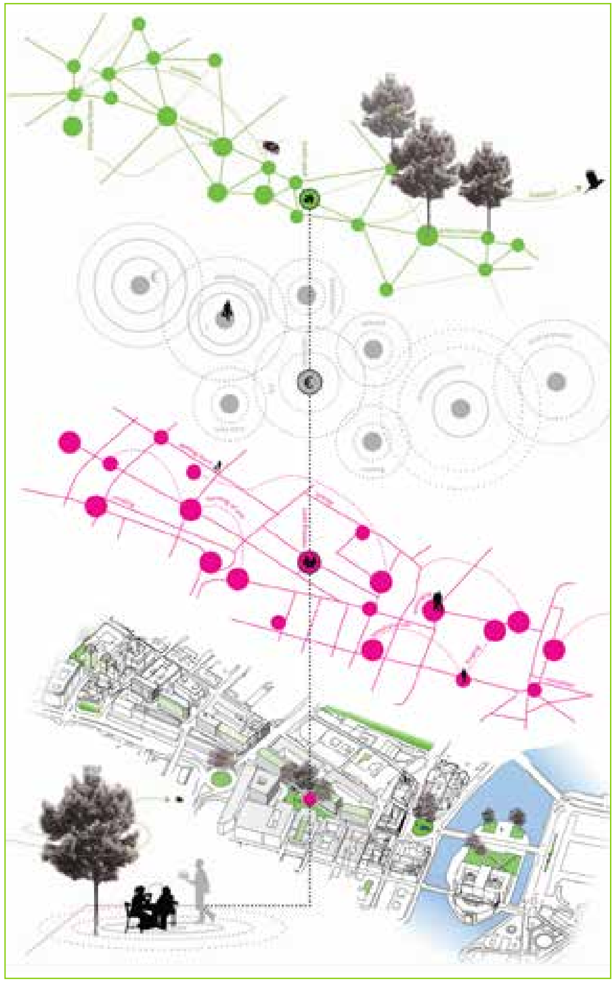
The benefit of incorporating these new dimensions into planning is in bringing together social aspects, economics, management of natural areas, and efficient use of resources, for which ecosystems may offer combined solutions.

Detailed Masterplan

Development of a detailed masterplan is the best stage at which to incorporate ecosystems services thinking into urban planning. The advantage is that a masterplan is sufficiently detailed to include practical measures and concrete proposals yet general enough to allow flexibility.

The value of existing green structures needs to be assessed, along with the risks if the green structures disappear. The ecosystem services that will be required when the area's functions and conditions change need to be identified. Everyone that has an interest in the area should be consulted, such as residents, companies, schools, outdoor associations and environmental organizations. In addition, knowledge about the existing ecosystems is required in order to identify indirect benefits, such as pathways and key biotopes. Other useful information includes the location of the most fertile land. A first step is to look at soil maps from the Swedish Geological Survey of Sweden (SGU). The location of water catchment areas is important in order to avoid building barriers that block water flows.

National level | Regional level | Masterplan level | Detailed plan level



The complex city - interconnections of biological (green structure), economic (grey structure) and social values (pink structure).

[Source for all the illustrations in this section: "Handbok om ekosystemtjänster i stadsplanering – en vägledning." (In Swedish.) ("Handbook on Ecosystem Services for Community Planning - a Guide.") Main author: White Architects, 2014.]

DETAILED PLANNING

Determining land use during detailed planning is central to the preservation of ecosystems in a region. This can include determining the proportion of natural land/park land in relation to the proportion of impervious areas. When an area is going to be changed, the design is discussed and planned in detail by the parties involved. There must be a dialogue between local residents and interested parties. Dialogue with residents reveals the ways in which an area is currently used and what is felt to be missing.

The municipality decides on the detailed plan and conditions of the development agreement. If land use is going to be regulated, the municipality has many opportunities to influence the design of an area.

The ecosystem services that will enrich the development are greatly influenced by the landscape. The boundaries of a detailed plan are clear but don't usually coincide with ecosystems boundaries. Therefore it is of great importance to see how planned developments may affect the surrounding areas.

Questions to ask:

- What are the views of relevant political groups about green and blue structures?
- Is there a budget within the project for studies or for obtaining supplementary information with the help of external competence?
- Is there the will to carry out workshops or will it be easier to arrange an external study?
- What issues are the project group and local politicians most concerned about?
- Is there valuable recreation space and nature in the municipality?
- What changes can be expected in the municipality as a result of future climate change and how can the the plan deal with these?

METHOD FOR INCORPORATING ECOSYSTEM SERVICES IN THE PLANNING PROCESS

The method is made up of four steps: identification, valuation, assessment and confirmation. A number of issues are addressed for each ecosystem service and planning level. These issues should be regarded as suggestions and may need to be adapted according to local conditions.

Identification. Find out which ecosystem services currently exist in the area. Which are missing? Identify the users of the ecosystem services. Much of the information may already be available. Carry out an ecological inventory and collect information on habitats, green connectors, noise levels and air quality.

Valuation. There are many ways to express the value of ecosystem services. Economic language is persuasive and makes it possible to compare nature with other interests, but this is not so simple in practice. However, indicators can be developed to describe values in both quantitative and qualitative terms.

Assessment. An assessment is made of what the area needs most, or can benefit most from maintaining. Create new ecosystem services if needed. Strengthen weak ecosystem services. Protect important existing ecosystem services and drop ecosystem services if other interests are more important.

Confirmation. Securing ecosystem services is the most important goal but can be the most difficult to achieve. As with many other issues, early dialogue is essential to the formation of common goals and to anchor decisions. This may, for example, lead to the establishment of a community association for management of the area.

The Movium group write in their book "The Whole City" ("Hela staden" – in Swedish only) about the role of green-blue structures in urban planning: "by planning and building neighbourhoods with attractive living environments, proximity to parks and other public spaces and places, stable environments are created where people are healthy and have a good quality of life. We must also consider the future by taking responsibility for biodiversity in the city and preparing for climate change."

In our view all planning should be preceded by a basic inventory and analysis of green-blue aspects of urban development.

PROVISIONING ECOSYSTEM SERVICES – SOCIETY'S RESOURCE BASE

The provisioning services are the material benefits delivered by ecosystems. They are essential for us to be able to live on our planet. Even though the majority of these services are generated outside city boundaries, there are reasons to keep them in mind in the urban environment, not least for the connections to cultural services related to education and understanding.

Food in the City

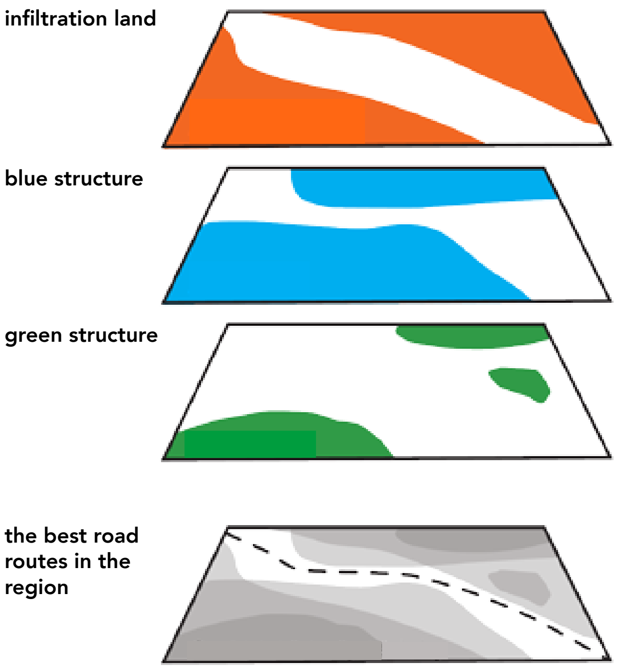
As more and more people live in cities, and as agriculture becomes industrialized and globalized, we are becoming further removed from food production. The result is that we do not understand the conditions required for food production. This can lead to thoughtless consumption of food that requires a lot of resources, toxins, energy or transport, or to exploitation of good cropland surrounding growing cities. In the long-term, when both land and plant nutrients are in short supply even in our part of the world, city dwellers' poor understanding of agriculture can significantly hamper food security. At the same time, there is currently a strong trend towards both organic and locally-produced food. Farmers' markets are a success in many European countries, restaurants with high aspirations look carefully for organic and locally-grown food, and allotment gardens and cultivation boxes are sought-after in cities.

Materials

Ecosystem services provide us with materials and energy. Great benefits can be gained by developing our understanding of these natural provisions within cities.

Production of Freshwater

Growing cities require growing freshwater resources. Water catchments areas are often quite close to cities and must be protected. Ecosystems, together with climate and geology, are important to the water cycle.



Principal for how various ecological values are weighted to achieve the best result.

CULTURAL ECOSYSTEM SERVICES – CONTACT BETWEEN PEOPLE AND THE ENVIRONMENT

Ecosystems come closest to us when they directly affect health and well-being. Nature can make us feel better, reduce stress, and help us recover faster from a sickness, both physically and mentally. There are numerous studies that show how even small green areas reduce stress and speed up recovery. That they improve health means that green areas have considerable economic value in terms of reduced health care costs.

Another important function of cultural ecosystem services is their educational value. Interaction with nature helps us to understand how natural processes work and how important it is to take care of functions such as food production, pollination and water purification. The more knowledge we have about nature, the better we become at protecting and caring for it.

REGULATING ECOSYSTEM SERVICES – NATURE'S OWN ENGINEERING

The regulatory services are nature's ability to regulate and mitigate factors in our environment that could otherwise become threats.

The use of natural systems for purification of stormwater is becoming increasingly common. In addition to being cost-effective compared to conventional stormwater systems, natural systems also add value in terms of biodiversity and recreation. Sewage water as well as surface and groundwater can be purified in ecosystems.

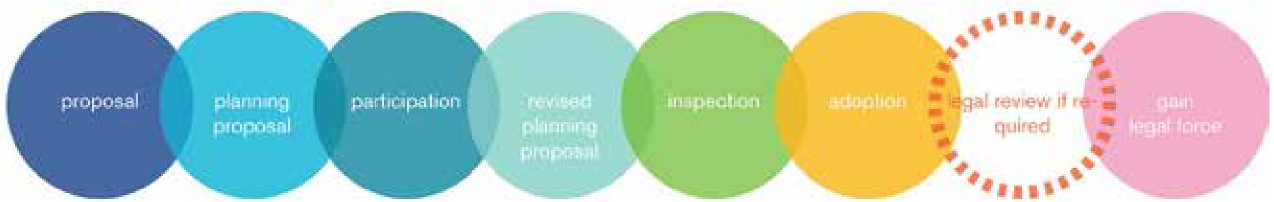
Greenery in cities purifies the air, primarily through the absorption of particles by deciduous tree leaves. Greenery can also help to reduce noise and the perception of noise. Green land surfaces, walls and roofs can absorb noise that would otherwise bounce off smooth facades and spread across the city.

Large, impervious, heat-generating and plant-poor areas create environments where it is difficult to manage water and to ventilate heat, so flooding and over-heating can be problems in urban environments. As global warming and climate change start to affect us, having well-functioning regulating ecosystem services becomes increasingly important.

A special service included in the regulating services is pollination. Pollination by insects is crucial for food production. It has been found that green areas in cities are very well suited for bees, as well as for flowers. Compared to large, homogenous agricultural areas, cities offers environments with both greater variety and fewer insecticides. In return, the bees produce richer crop harvests on land near cities, as well as honey and a profusion of flowers for city dwellers.

SUPPORTING ECOSYSTEM SERVICES – ESSENTIAL FOR ALL ECOSYSTEM SERVICES

The supporting services are fundamental processes and services that make it possible for both society and ecosystems to function. The supporting services rarely supply directly to society, but instead provide the necessary conditions for the other three groups of ecosystem services. Biodiversity, habitats or ecological relationships are not services in themselves, but without them, for example, many of the



The Swedish masterplan process.

plant and animal species that deliver regulating or cultural services cannot survive. The greater the diversity of species and habitats, the better the conditions for food production. Insects that pollinate are dependent on plants that bloom at different times of year, and different species of pollinators are dependent on different flower colours, scents and shapes. In this way, some plants, shrubs and trees that we do not directly see the benefits of can be crucial to the survival of the insects that pollinate fruit trees and other more obviously useful plants.

It is not only pollination that is crucial for food production. For instance, land with a great diversity of plant species can support species that fix atmospheric nitrogen into nutrients available to plants, species with large, deep roots that loosen the soil, species that interact with fungi and contribute essential nutrients, species that contain habitats or food for birds that control pests and species that are able to maximize extraction of solar energy at different times of the day and year. The services provided by all these different species help in turn the species that produce food.

Without shrubbery there is less bird-song: without spruce trees there are fewer oak trees. Many songbirds are dependent on the shrubbery that offers a safe environment for both nesting and foraging. Other birds rely on different tree species during different parts of their lifecycle. A classic example is the Eurasian Jay which eats acorns, but breeds in spruce forests and thus needs both oak and spruce. These birds help to establish new oak trees by collecting and burying acorns, some of which they forget about.

Urban gardening, Augustenborg, Malmö.
(Photo: Varis Bokalders)

Social meeting place by the water and green roof, Copenhagen.
(Photo: Varis Bokalders)

Identifying ecosystem services in existing or planned developments.

SUPPORTING ECOSYSTEM SERVICES

	IDENTIFY	*DOCUMENTATION, TOOLS, TIPS*	*ASSESS – CREATE, PROTECT, STRENGTHEN OR DROP*	*IMPLEMENTATION*
Biodiversity	• What areas have high biodiversity? • What areas are threatened in the short/long-term? • What key species/ indicator species/threatened species are found in the municipality/planning area? • Are there species or key species that are particularly important to the ecosystem? • What diversity is needed in the area? • How can the conditions be created for the desired diversity? • What functional groups are important for the ecosystem services in the area?	Masterplan, regional or local nature conservation plan, inventories of species/natural values, Swedish Species Information Centre, county and Swedish Forest Agency GIS inventories, local flora. City Biodiversity Index (CBI). Biotope Area Factor for public land. Dialogue with landowners, users and organizations.		**Masterplan:** Identify areas with rich biodiversity. Define areas where an in-depth nature inventory should be done and areas where biodiversity needs to be strengthened. **Detailed plan:** Design the valuable/designated areas as parks, nature or water areas. Make legal provisions regarding vegetation for important habitats such as meadows, wetlands and avenues. If these cannot be established as public land, make stipulations about land and vegetation. They must be followed by requirements for land use permits.
Valuable habitats	• Which habitats are there in the municipality? • Which ones are particularly valuable, and which ones are particularly sensitive? • Which ones are needed, with a view to the key species, pathways and ecological interactions? • Which natural areas have existed for a long time in the same place (these have a greater ecological value)?. • Have habitats disappeared/are habitats about to disappear due to land use change? • Is it possible to recreate habitats that have disappeared?	Masterplan, regional or local nature conservation plan/green-blue plan (if available), natural values inventories and management plans for the area, biotope map. The Swedish Society for Nature Conservation and residents and landowners may have valuable information about nature in the area.		**Masterplan:** Identify areas with valuable habitats. Define areas where an in-depth nature inventory should be made prior to development. Define areas where valuable habitats need to be re-created. See above under "biodiversity". **Detailed plan:** Consider the possibility of stipulating protective provisions (regarding natural and cultural history) for especially valuable environments, for example in parks.
Ecological interaction	• What do the pathways look like? Remember water pathways such as fish migration routes. • Are habitats close enough to each other so that the various species groups can move between them? • Are there any weak links that can be strengthened? • What characteristics must links have in order to function? • Have core areas and connections been identified? Take into consideration all green areas, including private gardens. • Are there any barriers to the spread of animals and plants? wIf so, how can they then be reduced?	Masterplan, regional or local nature conservation plan/green-blue plan (if available), biotope map. Connectivity analysis, barrier analysis. Keep in mind that ecological interaction takes place both spatially and between species.		**Masterplan:** identify and preserve important links as well as strengthen weak links. Compare with neighbouring municipalities. Identify and propose measures to strengthen possible pathways to isolated natural areas. **Detailed plan:** protect specific trees or natural elements (large oak trees, fish migration routes etc.) that are important for pathways and interaction.
The soil ecosystem and fertility	• Is there any particularly fertile land in the municipality? • What is it used for today? • Does the land in valuable green areas get an adequate supply of water and nutrients? • What flows are there, for example of garden waste, in the municipality? • Is there contaminated soil in the area? • Could floods bring pollutants that would affect large areas? • Can the soil absorb surface water so that pollutants are not spread? • Where can establishment areas be constructed? • Can soil compaction and the spread of pollutants be minimized? • How can affected areas best be restored?	Historical maps, land/environmental surveys, classification of agricultural land (according to the Swedish Board of Agriculture), the Geological Survey of Sweden (SGU). Visual inspection (is the soil dark? are there a lot of earthworms? do plants grow well?) or submit soil samples for analysis (water-holding capacity, organic matter content and soil chemistry).		Designate the most fertile soils for crops and animal husbandry, alternatively as natural land. Consider designating some land for crops, preferably on fertile soil. Strive not to build on or make these surfaces impermeable. Suggest composting and recycling of organic materials in collaboration with municipal technical departments/property managers. Perhaps designate a location for a compost facility.

REGULATING ECOSYSTEM SERVICES

	IDENTIFY	DOCUMENTATION, TOOLS, TIPS	IMPLEMENTATION
Improvement of air quality	• Are there high levels of air pollution in the municipality? • What are the sources? • Are there trees/shrubs or green spaces that can serve as shields between the built environment and sources of pollution? • What is the prevailing wind direction? • Can the wind carry away air pollutants? (Closed-street spaces near busy roads are particularly vulnerable.)	Air pollution maps or calculations, wind directions/wind roses (SMHI), Environmental Quality Standards (EQS) for air, traffic estimates. Deciduous trees are most efficient at capturing particles during the summer months, but conifers protect year-round. A combination is the best! Trees in the wrong places (e.g. in congested, closed street areas) can block the wind so that contaminants remain at ground level.	Identify problem areas. Cooperate with municipal environmental agencies or regional air quality protection agencies. Existing shelter belts of trees can be protected by requiring permits for cutting trees near roads, which can be legally binding or agreed on in consultation with the landowner. Are there other reasons (e.g. road safety) not to have shelter belts next to roads? Cooperate with municipal transport agencies. Avoid trees and shrubs in dense streets where people live.
Noise control	• Where is there disruptive noise now and where is it likely to be in the future? • Where can trees/shrubs be planted or green areas established to reduce the visibility of noise sources? • What proportion of busy roads are bordered by green areas and/or impervious surfaces?	Noise maps, noise simulations or measurements. National Board of Housing, Building and Planning noise guidelines. Interviews (how is the environment perceived?). Even relatively little greenery reduces the negative experience of noise. Sufficiently large/dense green areas also provide measurable reductions. Soft soil and green facades absorb noise. A combination of noise barriers with greenery is a good way to reduce the experience of noise.	Identify sources of noise as well as conflicts with long-term noise. Write in the detailed plan that permits are required for cutting trees and shrubbery near roads. Specify how much of parking areas must be made up of greenery, and how much land adjacent to roads must be green and pervious. Work with green noise reduction with architects and landscape architects. Can greenery be built on facades or courtyards to reduce noise? Dialogue with landowners about noise reduction measures, for example tree-planting.
Stormwater management	• Does the municipality have combined or separate systems for stormwater and sewage water? • Where are there good local conditions for dealing with stormwater? • Can stormwater be led to ponds/wetlands? • Do more ponds/wetlands need to be constructed? • Are there trees that should be felled?	Stormwater assessments, Swedish Geological Survey of Sweden (SGU) soil maps, topographic maps, stormwater guides. Gravelly soil in tree groves and "rain gardens" are effective ways to increase the proportion of pervious land. Green roofs are good at absorbing and delaying stormwater, especially those with greater soil depth, and trees can absorb large amounts of water.	Identify suitable surfaces for stormwater wetlands. Identify areas on public land where wetlands can be built. Indicate on the plan map. Discuss measures with property owners for local stormwater management including permeable surfaces and green roofs. Early collaboration with municipal infrastructure agencies. Can the Biotope Area Factor be applied?
Protection against extreme weather	• How will the municipality be affected by future climate change? • Identify areas sensitive to extreme rain, storms, heat waves and sea level increases. • Assess consequences of these.	Climate change reports (IPCC), regional/local action plans for climate change adaptation, local climate analyses, heat studies, topographic maps. Trees in dense urban environments can greatly reduce heat stress, through both shade and transpiration of water. Green surfaces and green walls and roofs are also important. Infiltration-prone land reduces the risk of flooding.	Identify risk areas (protected zones). Describe green protective measures. Greenery in cities cools and reduces flooding. Introduce permit requirements for removal of trees, vegetation and soil layers that will reduce excess heat in public places. Regulate the measures, for instance using the Biotope Area Factor to require planting of new trees and to determine the proportion of permeable surfaces.
Pollination	• How much agricultural land is in the municipality and how much of it is organic? • How much suitable habitat (both for nesting and foraging) is available for pollinators such as wild bees and bumblebees? • Are there any known colonies of pollinators? • How are they dispersed in the municipality/region? • Are there appropriate locations for hives?	Inventories of insects, space syntax analyses/connectivity analyses for pollinators, natural-value inventories, agricultural statistics (Swedish Board of Agriculture). Many pollinators have special habitat requirements. Different pollinators fly different distances. The greater the variety of pollinators, the greater the diversity of plants and the better the harvests.	**Masterplan:** Do an inventory of the municipality to ensure good distribution and protection of suitable habitats. **Detailed plan:** Attribute provisions in the plan, and make agreements with developers and managers. Cooperation with park management to ensure long-term maintenance of habitats.

ASSESS – CREATE, PROTECT, STRENGTHEN OR DROP

c/o city

CULTURAL ECOSYSTEM SERVICES

	IDENTIFY	*DOCUMENTATION, TOOLS, TIPS*	*IMPLEMENTATION*
Health	• What are the most important exercise trails? • Are there facilities for exercise in green areas within or close to the planning area? • What proportion of the residents live near parks or green areas? • Are there municipal guidelines? • How far are recreation areas from schools and homes for the elderly? • Does the area border on parks/natural areas? • Are there continuous green/blue corridors? • How accessible are green areas for various population groups? • How much nature-related sport activity is there?	Sociotope map, park programmes, documentation of the size/function/features of green areas. Dialogue with health centres, associations, sports clubs and schools. Analysis of residents' habitual routes, demographic data etc. Design of green/blue areas with use in mind.	**Masterplan:** Create guidelines for addressing shortcomings. Create a variety of green areas, small parks and larger natural areas for health-promoting activities. Develop guidelines for access to green areas, for example 200–300 metres to parks 2 ha in size and 2 km to green areas 10 ha in size. **Detailed plan:** Design public land so that it contains pedestrian and bicycle paths, swimming areas and exercise loops. Make green areas easily accessible. Collaborate with architects, and municipal park, sports and social agencies.
Experience for the senses	• What quiet environments and sound experiences (lapping waves, birdsong) are there? • What are the planning area's and surrounding area's most attractive natural environments? • How are they made accessible to as many people as possible? • How many beds in healthcare facilities have a view of greenery/water? • Is it possible to establish communal gardens? • How many bird watching towers, natural spaces or similar facilities are in place?	Site visits with municipal parks and environmental agencies (detailed plan), public participation (detailed plan and masterplan). Dialogue with local associations, such as historical societies.	**Masterplan:** Identify important places and qualities, both present and future. **Detailed plan:** Make protective provisions (regarding natural and cultural history) for public areas that is culturally valuable. Various green land-uses such as outdoor recreation, gardens, animal husbandry and camping can also be planned on city blocks. Locate pedestrian and bicycle paths and buildings, especially public buildings, so that they are well-used.
Social interaction	• Are green/blue structures connected with the municipality's most popular meeting places? • Are there/can there be continuous green corridors? • Is there/can there be greenery connected with meeting places, for example, cafés in parks, playgrounds or outside gyms in the woods? • What is the number of meeting places, and the number of passers-by?	Site visits with municipal parks and environmental agencies (detailed plan), space-syntax analysis, public participation (detailed plan and masterplan) to identify conflicts, for example horses/dogs. Public participation on-site (detailed plan and masterplan).	**Masterplan:** Identify important meeting places and blue/green corridors, as well as guidelines, for example, about planning street infrastructure. **Detailed plan:** Plan use of public land in relation to the areas where people are on the move. Coordinate placement of playgrounds, services, vehicle stopping areas, and public squares with green areas
Nature education	• Does the municipality have a plan for nature education in schools? • Are there guided nature tours for the public? • Is there a goal for the number of hours outdoors? • What are the destinations for school excursions? • Where do children spend time in the area? • What is the number of children at play? • Are there trees to climb, flowers to pick, insect nests to discover?	Site visits to schools, parks and environmental agencies. Dialogue with, for example adult education associations, the Swedish Society for Nature Conservation (SSNC), and historical associations. Dialogue with children and youth. Sociotope map.	**Masterplan:** Identify areas used for nature education, as well as for gardening and farming/urban farms, recreation centres, natural areas and allotment gardens. **Detailed plan:** Ensure accessibility from schools/preschools to natural areas/parks through street design, street location and pedestrian and bicycle paths. Locate schools/preschools close to natural areas.
Symbolism and spirituality	• Are there special elements (e.g. provincial animal/flower/sites) or other species/sites/habitats that are particularly important in the area/municipality? • Are there sites/can sites be created within the plan area with particular cultural or religious significance? • Are there existing cemeteries or are new ones planned?	Site visits with municipal park and environmental agencies (detailed plan). Public participation. Dialogue with the Swedish Church and other religious associations.	**Masterplan:** Identify places of particular cultural or religious significance and how they can be made accessible. **Detailed plan:** Ensure preservation of sites with protective provisions (relating to natural and cultural history). Ensure, for example, protection of individual trees of particular value, as well as permit requirements for felling trees.

ASSESS – CREATE, PROTECT, STRENGTHEN OR DROP

PROVISIONING ECOSYSTEM SERVICES

	IDENTIFY	*DOCUMENTATION, TOOLS, TIPS*	*IMPLEMENTATION*
Food production	• Is there local production of food that is consumed in the municipality, or are there the right conditions for this? • What arable land should be preserved (for example, particularly fertile land)? • Is there unused land that can be used for food production? • Is there currently any urban gardening? • Where could urban gardening, fishing, and mushroom and berry picking be carried out? • What synergy effects could cultivated areas and other green areas promote? • Is there a place to sell locally-produced goods (for example a farmers' market)?	Public participation with allotment associations, farmers, gardening associations, culinary crafts people, local associations such as the Federation of Swedish Farmers (LRF), sport fishing associations etc.	Regulate agricultural land, identify particularly valuable agricultural land, concentrate building developments, increase the density of existing urban environments, plan green areas near urban areas. Limit the amount of land covered with impermeable surfaces. Conduct a dialogue with developers/land owners in order to create cultivation areas (gardens or allotments). Set aside land for cultivation. Plan for urban gardening in dialogue with landowners. Ensure there are places designated for use as public squares or market squares.
Fresh water	• How is the municipality supplied with drinking water? • What natural areas are important for drinking water production? • Are there protected water areas? • Is there enough water in the long-term? • Can the groundwater level or quality be affected by developments?	Stormwater studies, municipal water and sewage plans, county administrative board protected areas and safety regulations. Groundwater maps or hydrological maps.	**Masterplan:** Identify areas with valuable habitats. Define areas where a detailed nature inventory should be carried out before development. Define areas where valuable habitats need to be recreated. See above under "biodiversity". **Detailed plan:** Consider stipulating protective provisions (relating to natural and cultural history) for particularly valuable environments (e.g. in parks).
Materials	• How are municipally-owned forests managed? • What happens to the raw materials produced? • Is there the possibility of better/different production (e.g. fibre/forest raw materials or food production)? • Do any of these forests have a greater value for other ecosystem services (for example, recreation or biodiversity)? • If there are trees near the city that are going to be harvested, can their materials be used locally?	Dialogue with local craftspeople, schools and landowners.	Identify the types of biofuels available, needs and supply. How can the forests be managed to balance production with other ecosystem services? Dialogue with municipal park management agencies or the equivalent regarding re-use of park/garden waste. Try to create formats and places for local sales and marketplaces.
Energy	• What is the potential for bioenergy in the municipality? • Is it being used locally? • Are there bioenergy resources within the planning area?	Forest inventories, silvicultural plans.	Identify access to and the need for biofuel, plus guidelines. Is there a long-term need for biofuel-fired heating plants? Plan for the cultivation of biofuels and biofuel-fired heating plants if appropriate. Is space needed for the distribution and storage of biofuels? Dialogue with municipal technical and environmental departments, and energy companies.

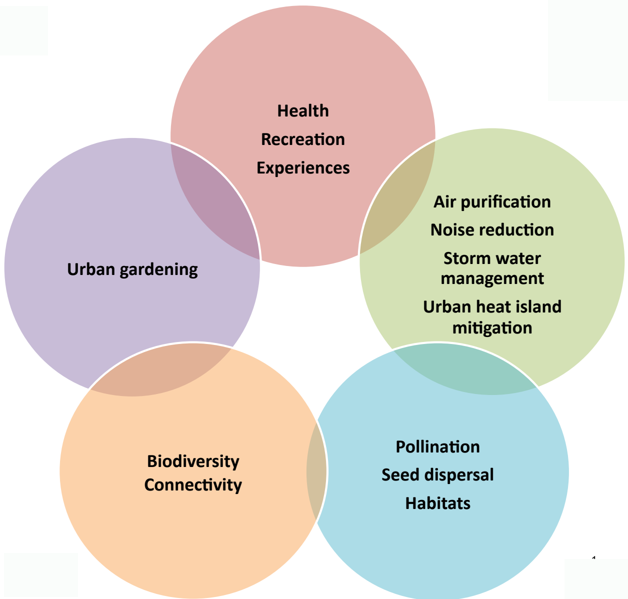
ASSESS – CREATE, PROTECT, STRENGTHEN OR DROP

QUANTIFICATION AND VALUATION OF ECOSYSTEM SERVICES

There is not only one way to evaluate ecosystem services, and placing a monetary value on nature is a matter of controversy. Just raising the topic of ecosystem services leads indirectly to a valuation of them. The project addressed various methods of valuation.

The first step towards being able to evaluate ecosystem services is to identify them, together with the users of each ecosystem service. It is often easiest to look first at the direct benefits, such as the provisioning services and recreation values although these ecosystem services are dependent on other supporting ecosystem services.

The next step is to map the ecosystem services. This mapping must also include the regulating and supporting ecosystem services which are important for the direct ecosystem services being mapped.



Urban ecosystem services studied by C/O City.
(Illustration: Felicia Sjösten, city of Stockholm)

The value of ecosystem services can be communicated in qualitative (descriptive), quantitative (data) and monetary terms. When evaluating ecosystem services it is therefore important to make use of ecological expertise for the area in question, including the greater region's ecology. Monetary valuation has advantages in a conventional cost-benefit analysis, since impacts of ecosystem services can be expressed in the same units (money) as other effects. At the same time it is difficult to arrive at monetary values that includes all values provided. Therefore monetizing ecosystems services is inappropriate in more complex situations that include a range of ecosystem services or when people hold a variety of ethical convictions about which values can or should be expressed in monetary terms. This is especially the case when it comes to the supporting and regulating ecosystem services.

SELECTION OF URBAN ECOSYSTEM SERVICES

Within the C/O City project, a number of ecosystem services that are relevant in a city context were chosen for closer study. The selection covers not only ecosystem services per se but also urban gardening (which has connections to several ecosystem services) and connectivity (which is an attribute of the landscape and is a basic requirement for many ecosystem services).

MANAGING BIOTIC ENVIRONMENTS – pollination, dispersing seeds, and living environments

In the urban environment, there is often a shortage of appropriate living environments for different types of plants and animals. Also existing habitats may be isolated from each other, so that plants and animals such as pollinators and seed dispersers cannot move from area to area. Considerable biodiversity is needed in the urban environment to support ecosystem services such as pollination of flowers, urban fruit and vegetable growing, and pleasant living environments (with, for example, greenery and bird song) for recreation, recuperation and social interaction. Green roofs have been studied, as have walls with climbing plants, parks, gardens, and natural areas.

Urban gardening is a recreational activity that contributes positively to our health. Growing your own vegetables is in turn dependent on pollination, a service that bees, butterflies and other pollinators offer. However, pollinators are dependent on more than just blooming flowers for their survival. Varied environments are required where they can build nests and find other food resources during periods of the year when our crops are not in bloom. These areas must be relatively close to each other or be connected – an issue of connectivity.

HEALTH

There is a lot of evidence that green roofs and other green areas in cities can provide habitats for many different plants and animals. Studies also show that spending time in green environments (of various types) results in positive effects for people's physical and mental health. What all the studies find is that the green environments need to be close to residential areas or that people, for other reasons, need to spend time in them daily, or almost daily.

Examples studied are pre-school playgrounds, parks, gardens and other urban green structures. The frequency of visits to urban green areas and the length of stay decreased significantly with distance between the home and the green area. A critical distance seems to be 300 metres. Access to green and or natural environments increases motivation for physical activity. Pre-school children spending time in pre-school playgrounds with lots of greenery and natural or nature-like environments are better ability at concentrating and have better motor skills (Grahn et al. 1997) than children in preschools with traditionally designed playgrounds. Studies also show that absence due to sickness is lower among pre-school children who spend a lot of time outside in green environments. Several studies show that spending time in green environments reduces stress levels.

Health and recreation connected to biodiversity and natural environments

In the urbanization process, rocky knolls, stony land with pine trees, old trees and natural paths between buildings often disappear. What does it mean that walks on blue anemone-covered hills and in a hazel tree forest are replaced by walks through streets and well-tended city parks? Several studies report faster, greater and more longer-lasting positive effects on wellbeing, stress reduction, mood and ability to concentrate during and after spending time in high-quality natural areas rather than in a green urban environment.

Several Swedish studies show that the experience of forests, untouched nature, species diversity and nature sounds are very valuable recreational qualities of forests near urban areas. The studies clearly show that greenery in the urban environment has a positive impact on health and that it is important to be close to green relaxing environments, and that spending even a short time in these environments affects mental processes and reduces stress.

Ecosystem services connected to recreation near water

There is a clear relationship between health and access to water areas. Spending time near water – walking, swimming, engaging in sports and other physical activity on or connected to water – provides exercise and/or relaxation, a positive experience of nature, and increased insight into our interconnectedness within nature. Recreation near water takes place at lakes/oceans, docks, streams, wetlands, beaches, natural areas near beaches and built swimming areas. Water areas close to cities make possible a number of activities: swimming, sunbathing, snorkelling, diving, sailing, windsurfing, canoeing, kayaking, water-skiing, wakeboarding, sport fishing, using motor boats and water scooters, skating/long-distance skating as well as studying plants and animals, bird-watching, walking and jogging near beaches.

Methods of quantifying recreation include measuring the number of organisation members, visitor frequency to recreational areas and participation in competitions related to recreation. The methods used to try to evaluate ecosystem service recreation are the hedonistic method, the travel cost method, and the willingness to pay method. The 72 swimming areas in Stockholm have been valued at 23 million SEK per year (minimum method) and at 1,412 million SEK per year (reference standards method based on 200,000 visitors).

URBAN GARDENING

Without being an ecosystem service in itself, urban gardening creates and reinforces a number of ecosystem services. In Sweden there is a 100-year-old cultural heritage of urban gardening that evolved from a focus on self-sufficiency to become a social movement that contributes to biodiversity and also provides opportunities for recreation, learning and self-sufficiency. There is an abundance of important pollinators in allotment gardens. As for groups of animals with specific functions – such as insectivores and seed-dispersers – the composition of insect communities and seed-dispersers is greater in allotments than in parks and the species composition of insectivores is greater in allotments than in cemeteries.

There is a high demand for gardening in urban environments, which in Stockholm is illustrated by guerrilla gardens, balcony gardens and long waiting-times for allotments. Recreational gardening in Sweden has the potential to produce 700,000 tonnes of crops per year with an economic value of 30 million SEK.

Pallet collar garden beds, the Stockholm Royal Seaport, Stockholm. Simple growing for many people in diverse city locations.
(Photo: Christina Wikberger)

BIODIVERSITY AND CONNECTIVITY

To illustrate the relationship between urban ecosystem services and biodiversity, connectivity has been included as an example of a crucial supportive ecosystem service in the urban landscape, as it is a basic prerequisite for the processes that maintain biodiversity. Connectivity means relationships and processes that function between areas. As biodiversity in turn is a prerequisite for many other ecosystem services, connectivity is associated with delivery of these other services. Connectivity is always species-specific, i.e. connectivity looks very different depending on which species are being studied. For example, birds have much greater mobility and a broader food intake than soil-dwelling insects, and are therefore less sensitive to fragmented landscapes.

The results of studying connectivity show the activity radius of the pollinators and seed-dispersers assessed, as well as the type of habitat qualities that need to be within the radius of activity so that these ecosystem services can continue being delivered.

STORMWATER MANAGEMENT

Stormwater runoff from built-upon and impermeable areas is greater than from natural land, and stormwater flows must be controlled to prevent flooding, erosion and polluted stormwater from entering lakes and streams. Conventional solutions with conduits, stone caissons and various forms of artificial storage systems can be useful but are often expensive and do not allow the stormwater to benefit the ecosystem. Since stormwater from roofs, courtyards and local streets is not so contaminated it is desirable to build natural systems with ditches, ponds, wetlands, temporary flooding areas at low points, and delays provided by soil and vegetation. How much are these ecosystem services worth? Quantification has been carried out for flow control and treatment effects, as well as for the significance of trees for stormwater control.

The results show, for example, that a 1,000 m^2 area of land covered with vegetation and with <300 mm soil depth (constructed for the purpose with specially made soil with large hollow spaces and ability to hold water, pumice, etc.) can retain about 75 m^3 of water. Based on the cost of stone caissons, stormwater cassettes and pipe storage (which then do not need to be built) a substitute value has been calculated at from 75,000 to 375,000 SEK (only initial capital costs). The estimated reduction of stormwater runoff due to a single tree is 20 m^2/year.

AIR PURIFICATION

Trees and other vegetation have the ability to reduce air pollution and contribute to improved air quality. Particles and nitrogen are among the air pollutants that contribute to respiratory and cardiovascular disease. Particles leave the air by sticking to vegetation surfaces, while nitrogen gas is absorbed by plants.

The city of Stockholm's green areas receive an annual deposit of vehicle exhaust particles and coarse particles (PM10) of approximately 1,500 tonnes, including a re-suspension factor of 50 % as particles settle first on vegetation and return to the air during windy conditions. Green areas show an annual net deposition of particulate matter (PM10) of almost 800 tonnes. Coniferous and mixed forests account for 99 % of the deposits. Net annual deposition amounts to 45 % of particulate emissions from road traffic in the region.

Results show that reduced exposure to air pollution can have a number of positive effects. Some of these effects can be assigned a monetary value, for example, savings in medical care and reduced productivity losses (reduced ability to work and absence from work) as a result of illness and problems from air pollution. Greater Stockholm's green areas contribute savings of between 71 and 83 million SEK per year. The decreased productivity loss has been valued at between 262 and 307 million SEK per year.

However, there are theories and findings that suggest an increase rather than a decrease in air pollution in some street environments where there are trees. This is because mixing of the air can be reduced in some cases and thus a smaller portion of contaminants are vented away. In such environments it is best to work with low vegetation such as greenery on facades and roofs.

NOISE CONTROL

Noise is a major problem and an important issue, with high socio-economic costs. About 20 % of the population of the EU suffer from noise levels considered unacceptable (> 65 dB) and a further 40 % live in "grey zones" (55–65 dB). Results from a large number of studies show that traffic noise causes changes in physiological systems (for example hypertension), cognitive deficiencies (such as poor sustained attention, and problems with memory and concentration), sleep disturbance, changes in social behaviour, psycho-social stress-related symptoms, emotional problems and difficulties with motivation.

Under the auspices of the Hosanna project 13 international research institutes studied vegetation as a tool for noise reduction over a five-year period. Some results were: that a green facade can reduce noise by up to 3 dB(A), a green roof by up to 8 dB(A), and a low green barrier by up to 10 dB(A). Combinations of green measures and other sound-reducing elements are effective and can further enhance the effect. Nature generates sounds that we experience as positive and that reduce our negative experience of noise.

MICROCLIMATE MANAGEMENT

In recent decades the planet's cities have undergone significant temperature increases. Urban heat-islands become so hot that they lead to both sickness and death. During a hot summer day, surfaces in cities can reach temperatures that are 27–50 °C warmer than the air temperature. The elderly are especially affected. In Europe in the summer of 2003, 70,000 people died due to the heat. Whilst heat-related deaths have decreased due to improved health care, greater access to medical facilities and more air conditioning, these are solutions that cost more, use more energy and increase environmental impact.

Urban green structures, area and type of vegetation, have a significant impact on local climate and temperature. Blue structures, the area and depth of lakes, rivers and oceans also have regulatory effects on temperature and local climate. A tree provides shade and cools by evaporation as long as there is water available. Simulations show that trees can lower the average temperature by 0.3–1 °C in a city, and in some cases by as much as 3 °C.

EXAMPLE: The Eurasian Jay in The Royal National City Park

Results from Felicia Sjösten's Masters thesis, Stockholm Resilience Centre, University of Stockholm.

The Royal National City Park in Stockholm provides a unique environment with its magical coniferous forests and many giant oak trees. To a large extent we have the Eurasian Jay to thank for the oak trees. This colourful bird from the crow family collects and hides acorns in food stashes, some of which are forgotten or left behind, and thus new oak trees grow in the landscape. The oak trees are a much appreciated feature of the Royal National City Park and contribute to a high level of biodiversity. The value of an Eurasian Jay pair in this large park is estimated at 35,000 SEK (Hougner et al. 2006).

However, these birds are not only dependent on acorns for their survival but also on coniferous forests to build their nests in. As the Eurasian Jay is a common prey for the goshawk, it needs the dense coniferous forests to escape to and to raise its young, in order to increase its chances of survival. In more open areas, the Eurasian Jay is easy prey. The process of spreading acorns is thus dependent on the presence of both oak and coniferous forest areas in close proximity to each other. In other words, i.e. on a high degree of connectivity.

In her Masters thesis at the Stockholm Resilience Centre, Felicia Sjösten examined the degree of connectivity for Eurasian Jays in the northern and southern part of the park as a measure of the seed dispersal service. The results showed that all the existing stands of oak trees in the area were accessible thanks to the nearby coniferous forests (< 2 km distance by air). However the oak tree stands outside the northern and southern parts of the park were not accessible, due to the absence of nearby coniferous forest areas (> 2 km).

The results point to the importance of management (preservation, establishment and maintenance) of urban natural areas based on basic landscape processes in various temporary and spatial contexts, e.g. complementing the landscape with natural elements that strengthen important ecological processes on a scale that extends far beyond the small natural areas where the management takes place, and takes into consideration present and future needs.

Eurasian Jay. (Photo: Johan Pontén, city of Stockholm)

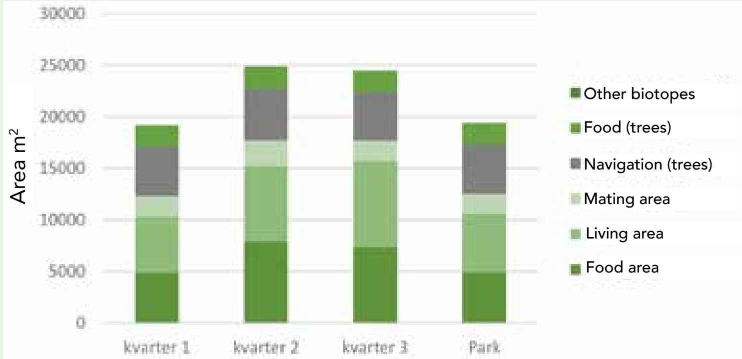
(Illustration based on and modified from Hougner et al. (2006) and used with permission of Barthel et al. (2013). From the report "Economic valuation of a seed dispersal service in the Stockholm National Urban Park, Sweden")

EXAMPLE: Pollination Potential in The Stockholm Royal Seaport

Results from a cooperative pilot study by Stockholm University, KTH Royal Institute of Technology, Stockholm, and C/O City. Contributors: Meta Berghauser Pont, KTH; Lars Marcus, KTH; Felicia Sjösten, City of Stockholm; Nils Göransson, City of Stockholm; and Erik Andersson, Stockholm Resilience Centre.

A pilot study carried out by KTH Royal Institute of Technology assessed a method of quantifying biodiversity using the pollination ecosystem service in Norra Djurgårdsstaden, the Stockholm Royal Seaport. The method tested was Space Syntax – an analysis tool for spatial dispersion. The tool was adapted to apply to bumblebee and honeybee movement patterns in urban environments. The potential was measured in the number of resource areas (foraging, nesting and breeding sites as well as objects for navigation in m²) that bees could utilize within three planned courtyards and a beach park, and the resources they could access from there in the surrounding environment based on each possible linear movement (the lines in the images below).

Six-spot burnet. (Photo: Helene Pettersson)



Resources accessible to bees within 250 metres when all the courtyards in the Stockholm Royal Seaport are implemented.

(Illustrations: Meta Berghauser Pont, KTH)

The results show that at distances of 250–500 m (buffer rings in the image on the lower left), the total accessible resources reach 25,000 to 140,000 m² from the city block with the highest connectivity to the surrounding area (i.e. where the most movement is possible). For the city block with the lowest connectivity to the surroundings, at the same distance, the total resources accessible were only 15,000 to 50,000 m².

The more resources that can be reached, the greater the likelihood that bees are found in the area, and thus the pollination potential increases.

The results illustrate clearly the importance of taking into account the placement of city blocks with resources for pollinators, and of buildings in relation to their surroundings, i.e. placing resources close to other resources and facilitating movement between them. The study shows that a city block with good connections to the surrounding area has the potential to contribute to increased connectivity in other city blocks that do not have good connections to the surrounding area. City blocks with good connections to the surroundings thus act as "stepping stones" which increase the possibilities for other nearby city blocks and therefore the whole area's potential for obtaining the ecosystem service.

Pilot study test area.

Possible movements from resource surfaces within city blocks and the park.

Indicators for Ecosystem Services

C/O City developed tools to facilitate the planning of ecosystem services, recognising the need for monitoring to ensure that planning has the desired effect. The tools can be applied at different scales (from property level to city-scale) and monitoring is therefore needed at different levels. To address the need for monitoring, the City Biodiversity Index (CBI) was used to compile indicators at the city district level.

The following questions arise:

- What can be monitored?
- What indicators and data can be used?

The City Biodiversity Index (CBI) is a method of monitoring used by several cities, including Brussels, Curitiba and Stockholm. It consists of 23 indicators covering the following aspects: the city's biodiversity, ecosystem services linked to the city's biodiversity, the city's efforts, governance and partnerships to preserve biodiversity.

Based on the CBI, C/O City worked out a number of indicators that are suitable for use at the city district level to monitor ecosystem service functions.

When monitoring, it is important to choose a base year, to select the indicators and to balance the choice between ecological and social indicators.

Rich biodiversity with a diversity of animals and plants is positive regarding both biological and social aspects.

To monitor ecosystem service functions at the city district level, good documentation is needed, such as:

Ecological aspects: Biotope maps, map data/analyses, habitat networks, species inventories, bird inventories, land use maps, decisions on protected areas, planning maps, development documents, and construction documents.

Social aspects: Sociotope maps, park programmes, citizen surveys, noise surveys, user contracts, project budgets.

Proposed indicators at the city district level:

ECOLOGICAL ASPECTS

- Natural spaces and opportunities for recreation, habitats for animals and plants and stormwater management: portion of the natural area of the city district (hectares).

- Connectivity in the landscape, biodiversity, pollination: Portion of the natural area of the city district that is linked (hectares).

- Number of birds, species richness of birds, biodiversity: Number of naturally occurring birds in other areas, for example built-up areas.

- Pollination, biodiversity, resilience: List the number of occurring functional groups and key species groups.

- Regulation of water and local climate: The portion of permeable surface of the city district's land area (in hectares).

- Carbon storage and cooling effect: The crown-covered land area (hectares).

"Urban villas", Malmö. The balconies are reinforced for cultivation beds. There is 30 cm of soil under the floor boards. Any number of boards can be removed in order to access the soil for gardening. (Photo: Varis Bokalders)

Photo: Johan Pontén

(Photos: Felicia Sjösten)

Flourishing green roofscape in Malmö.
(Photo: Christina Wikberger)

Wall with edible plants. (Photo: Felicia Sjösten)

SOCIAL ASPECTS

• Access to nature for recreation: size of park with natural spaces as well as protected or ensured natural spaces per 1,000 inhabitants.

• Access to and time spent in parks and nature:
1) Access to swimming beaches.
2) Access to parks and nature.
3) Time spent in parks or natural areas.

• Budgeted green solutions (for example, stormwater solutions, noise reduction, parks and other green areas): budgeted biodiversity.

• Institutional capacity in the city district (for example urban farms, nature schools, local associations connected to "green issues", outdoor oriented preschools):
1) Total number of initiatives and/or number of active organisations.
2) Number of initiatives and/or number of active organisations per person.

• Public participation (for example TEEB workshops, city district administration activities):
1) Number of participants/total number of residents in the city district.
2) Number of participants/events arranged in the city district.

• Effect of vegetation on sound quality/noise: Noise (dB).

• Allotment gardens/cultivation boxes/taking care of beehives/city land maintenance/nearby areas etcetera: Number of user agreements.
• Activities connected to nature experiences arranged by the city district (for example, gardening and bird watching):
1) Number of activities/year.
2) Number of activities and number of participants/year.

Solar cells can be incorporated nicely with establishment of a green roof. (Photo: Christina Wikberger)

(Photo: Christina Wikberger)

Green Building Envelope – Moisture Conditions, Energy Consumption, Experiences

In Sweden there is increasing interest among developers and property owners in installing green areas on roofs and walls. There are many reasons to use green areas in a building envelope. Peak load on the stormwater network is reduced when there is a downpour, biodiversity in cities increases, the street climate can be influenced by changed sound, wind and temperature conditions etc. There are also social aspects such as increased well-being among users. Due to climate change Sweden may have higher temperatures and increased precipitation with more frequent downpours in future. This makes it more important to build knowledge about how green building envelopes affect – amongst other things – moisture and temperature conditions in constructions as well as energy consumption.

Experiences from production and management of green roofs

Advantages:

• Enable brand development.
• Contribute to biodiversity.
• Provide pleasant areas for social activity.
• Contribute to the Biotope Area Factor.
• Give points in environmental certification.
• Regulate stormwater during downpours.

Issues raised:

• Risk of difficult-to-discover leakage, especially on low-angle roofs.
• Durability, how will the waterproof layer perform as it ages?
• Fire safety during dry periods with dry plants on the roof surface.
• Ducts, connections and joints as moisture-sensitive points.

Planning considerations:

• Check the construction can withstand the weight of the green roof when the plant substrate is saturated with water.
• Plan bearing capacity with regard to transport and machines during the construction phase.
• Carry out a moisture safety plan.
• Choose the right material for the waterproof layer and verify that it is watertight.
• Make sure the waterproof layer is not damaged during transport or construction.
• Plan de-watering of the roof well.
• Choose the right plant substrate.
• Choose robust and hardy plants.
• Check whether a watering system is required.
• Carefully plan the timing for installation of the green area in the building process.

Operation and maintenance:

• Choose systems based on the developer's level of ambition regarding operation and management.
• Write instructions for operation, management and maintenance of the green building envelope.
• Determine routines for watering and management of watering systems.
• Regularly check draining control wells.

Planning and construction of wells is important in order to avoid the risk of leakage. Planning for moisture protection must document moisture protection solutions. (Photo: Eva Sikander)

The KI auditorium in Stockholm has a sedum roof. The main reason for choosing a green roof was to even out the stormwater load during heavy rain. (Photo: Eva Sikander)

Principles for Green Roofs and Walls

Green roofs are roof structures which are covered with some form of vegetation. The type of vegetation depends on what the roof will be used for and how much soil or plant substrate the underlying structure can support.

There are three types of green roofs: Extensive, semi-intensive and intensive (*see Table 1*). However, for the sake of simplicity, classification is made according to the depth of the growth substrate layer of the roof.

The most common types of green walls are seen on buildings that have climbing plants along the facade, but there are several other types of green walls. The basic classification is between green facades and living walls. Green facades have plants planted either at the bottom of a facade (in the ground or in pots) or above, which then grow along the wall. Living walls have plants planted on the facade. Such a system was used and evaluated in field trials at SP Technical Research Institute (*see Figure 1, page 37*).

Results of Measurements/Simulations of Green Building Envelopes

Comparisons between simulated and measured values show that the simulations correspond well with reality and can be used for the development of green building envelopes.

Temperature: Green walls have a temperature-moderating effect, depending on the thermal mass of the growth substrate, the cassettes and the plants. The outside of the wall behind the cassettes gets warmer during cold periods and cooler during hot periods when compared to a normal wall.

Moisture: The relative humidity in the wall behind the plant cassettes is higher (up to 80 % RH) during periods when the green wall stores the cold from cold nights (which risks wall-fouling) and lower during periods when the green wall stores heat from warm and sunny days.

With increased insulation thickness and reduced U-values the relative humidity shifts to higher values in the outer parts of the walls, both for an ordinary wall and for green walls. Therefore, a plan to properly deal with moisture should be implemented for green walls and roof structures.

There is higher relative humidity in structures with green roofs compared to conventional roofs. In the cases analysed in the project an unventilated, well-insulated roof dealt with moisture better with a conventional roof cover than with a green roof. On the other hand, the ventilated, well-insulated green roof dealt with moisture better than the unventilated roof.

Energy: In a well-insulated building in Sweden, energy consumption is not significantly affected by a green building envelope. In a hot and humid climate with poorly-insulated walls, energy consumption for cooling is reduced significantly by a green building envelope due to the thermal mass of the wall modules, the shading effect and some evapotranspiration from the plants and substrate. However, such walls require some irrigation and the roof must be suitably designed for the substrate and growing conditions.

2 (6)	2	5	2	4	8 (5)
1	1	2	3	1	4
1 (6)	7	6	4	8	9
8	7	5	1	3	2
3	2	8	8	7	9
7	1	5	8	3	1
7	9	9	7	9	6
2 (5)	6	2	8	5	4
1	9	7	7	1	1 (6)
8	5	5	6	3	3
3	8	4	3	4	2
9	9	1	3	2	6

PLANTS
1. Lingonberry
2. Cranesbill
3. Holly
4. Bergenia
5. Great wood-rush
6. Edelweiss
7. Wild strawberry
8. Woodland sage
9. Chives

Above: Planting diagram for plants on a green wall at SP, Technical Research Institute of Sweden.
Left: Plants one year after planting, at the end of June 2014.

Roofscape on Katsan, White Architects roof garden, offers a recreational area for the staff of the office building.
(Photo: Eva Sikander)

There are several commercial systems for green walls, both cassette systems with planting pockets and climbing plant systems.
(Photo: Christina Wikberger)

Table 1. Classification of green roofs. Extensive roofs weigh less than other forms of green roof and when an existing building is equipped with a green roof, there is often no other option than an extensive roof.
(Source: Green Roof Guide)

GREEN ROOF	EXTENSIVE	SEMI-INTENSIVE	INTENSIVE
DEPTH OFF PLANT SUBSTRATE	< 10 cm	10–20 cm	> 20 cm
OTHER CHARACTER-ISTICS	• Low maintenance (usually not even irrigated) • Limited water retention • Includes both pre-grown vegetation mats and substrate	• Requires moderate maintenance and occasional irrigation • Rainwater attenuation • Supports vegetation • Wider range of plants than extensive roofs	• Requires intensive maintenance and may have to be irrigated • Recreation area • Water attenuation

GREEN WALLS	GREEN FACADES		LIVING WALLS	
CHARACTERISTICS	Grow along the facade upward from the soil/pot or down from a pot. • Climbing plants • Clinging vines • Hanging plants		Grow in different types of planting containers attached to the façade.	
SUBGROUPS	Direct Vegetation	Indirect Vegetation	Soil-based	Hydroponics
	• Attaches directly to the facade and climbs along it	• Climbs along a net, wires, or trellis in front of the facade	• Planted in soil	• Planted in, e.g. pockets of felt or mineral wool • Watered with a nutrient solution (minerals)

Table 2. Green walls, properties and characteristics.

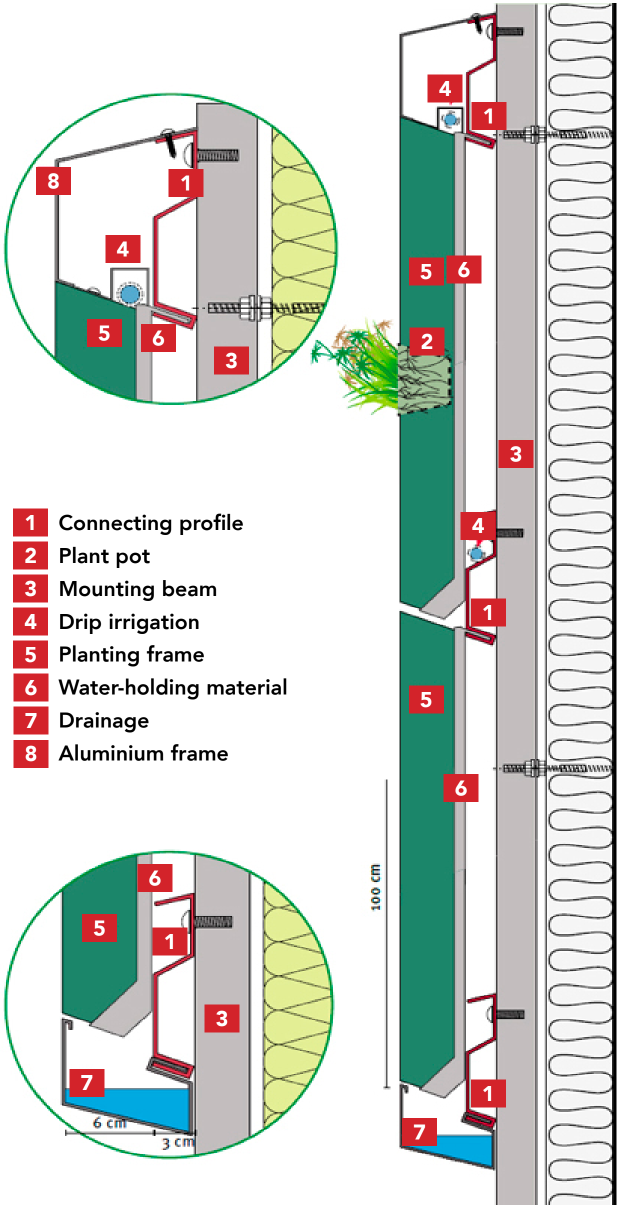


Figure 1. Structure of plant cassettes on the outside of an existing wall. (Source: Optigreen)

EXAMPLE: Plants and Animals on Green Roofs in Stockholm

From Michaela Lundberg's Masters thesis in biology at Uppsala University.

A green roof is a roof where vegetation has been planted. The purpose of such roofs can vary. Some roofs are used as outdoor milieus for people, others as a way to compensate for the removal of the natural environment during construction. There are two main groups of green roofs, intensive and extensive. The difference is that an intensive roof has a much thicker soil layer than an extensive roof. Therefore the types of species that can be planted on an extensive roof are very limited – they must, above all, be very hardy. There is a much greater choice of species for intensive roofs. Sedum (Crassulaceae) is the most common type of plant used on extensive roofs.

The thesis examined roofs in Stockholm, the different species of plants and animals that can handle such an environment and what these roofs looks like when not taken care of. Nine different roofs in different parts of Stockholm were visited. Moss samples were gathered and birds were observed. Soil samples were taken to find out, for example, the carbon and phosphorus content. A comparison was made of the way in which the different plant species covered the roofs, depending on whether or not the roof was sloped or had any form of annual maintenance.

Biodiversity on a green roof.

One of the roofs stood out from the others as it was the only intensive roof in the study. This roof had very few species when planted, but the number had increased at least tenfold. The slope did not make much of a difference. In a comparison between the roofs with and without maintenance, more sedum plants were found on the maintained roofs. These roofs also seemed more popular with bumble bees, bees and wasps. Butterflies were also found on these roofs and they seemed to be attractive as breeding areas and refuge for various birds.

Green roofs:
• Reduce the risk of flooding during downpours since the soil and plants absorb the water.
• Plants clean the air. Their efficiency depends on the choice of plants (grass is more efficient than sedum).
• They reduce noise since sound waves don't reflect as much as from hard surfaces.
• Correctly-designed green roofs act as dispersal routes for plants, insects and birds.
• They contribute to climate regulation in cities – the temperature on the roof is more even.
Plants clean the air. This is dependent on the choice of plants (grass is more efficient than sedum).
• They reduce noise since the sound waves don't reflect as from hard surfaces.
• Correctly designed green roofs act as dispersal routes for plants, insects and birds.
• They contribute to climate regulation in cities – the temperature on the roof is more even.

However:
• They are more expensive to build than conventional roofs and require some maintenance.
• They are heavier, especially when it rains, and require constructions that can support them.
• They contain a waterproof layer than can contain toxic chemical substances.

Two of the green roofs studied.

Ecosystem Services in Environmental Certification – Analysis of the Environmental Certification Systems BREEAM-SE, BREEAM Communities and CEEQUAL

An environmental certification is an assessment of the environmental sustainability of, for example, a construction, an infrastructure or a city district development project. Based on a certification system, a building or an area can obtain a certificate showing its environmental performance. There are several certification systems on the international market.

The systems considered in this project the systems were BREEAM Communities (city districts), BREEAM-SE (properties) and CEEQUAL (infrastructure projects). These three certification systems were analysed to see how they take ecosystem services into account. Based on the analysis, the criteria related to ecosystem services were identified. The work has resulted in a proposed process for work with ecosystem services within each respective certification system. All these certification systems currently have specific criteria for itemising and analysing ecological values. None of the systems, however, uses the ecosystem services concept.

Each certification system is divided into assessment stage, implementation strategy and management over time. These processes have been supplemented with suggestions about how ecosystem services can be strengthened with supplementary assessments and appropriate competencies, as well as with the help of the Biotope Area Factor (BAF) planning tool. An analysis of how ecosystem services are dealt with in the BAF shows that the tool both directly and indirectly connects many different ecosystem services, and is a good management tool that can support and complement the certification systems.

In the study, a rough matrix analysis was carried carried out first, in which ecosystem services were placed on the x-axis and the selected criteria from environmental certification systems, corresponding to the Biotope Area Factor, were placed on the y-axis. Based on this analysis, a number of important criteria from the certification systems were chosen for consideration, criteria with a potential for use with existing ecosystem services and for developing new ones. Finally, a process for working with ecosystem services was developed for each certification system. These processes are meant to serve as a guide for the selection of criteria and to clarify how these criteria are important for the ecosystem services. By highlighting how ecosystem services can be handled within existing certification systems, the project contributes to the development of planning and monitoring tools for urban ecosystem services. There are currently several different lists of ecosystem services. The Millennium Ecosystem Assessment (MA, 2005) was one of the first, but it did not become well known. When "The Economics of Ecosystems and Biodiversity" (TEEB, 2008) was released, it had a greater impact. The Swedish Environmental Protection Agency (EPA) has since made a list adapted to Swedish conditions (EPA, 2012). In this project, the TEEB and the EPA lists were used.

TEEB	EPA subcategory	Section
food	food from cultivated land plants	provisioning
freshwater	drinking water from surface water	
freshwater	drinking water from groundwater	
	water for irrigation	provisioning
local climate and air quality regulation	water for cooling	provisioning
water purification	finishing treatment with the help of plants	regulating
water purification	finishing treatment with the help of microorganisms	regulating
local climate & air quality regulation/water purification	dilution, decomposition, remineralisation & recirculation	regulating
local climate & air quality regulation/water purification	filtering	regulating
local climate & air quality regulation/water purification	collection, absorption	regulating
determination of the amount of carbon/carbon storage	global climate regulation	regulating
local climate and air quality regulation	local and regional climate regulation	regulating
local climate and air quality regulation	noise reduction	regulating
moderation of extreme events	moderation of runoff and flows	regulating
moderation of extreme events	flow regulating water storage	regulating
erosion control and maintenance of soil fertility	erosion protection	regulating
	protection against avalanches and landslides	regulating
pollination	pollination	regulating
pollination	dispersal of seeds	regulating
pollination	living environments during youth stage	regulating
pollination	living environments for other than the youth stage	regulating
aesthetic appreciation and inspiration for art, culture and design./spirituality and feelings for a place	landscape character - natural heritage	cultural
aesthetic appreciation and inspiration for art, culture and design./spirituality and feelings for a place	landscape character - cultural heritage	cultural
recreation as well as physical and psychic health	recreation, organized	cultural
recreation as well as physical and psychic health	recreation, not organized	cultural
recreation as well as physical and psychic health	sport activities	cultural
aesthetic appreciation and inspiration for art, culture and design./spirituality and feelings for a place	aesthetic values	cultural
species habitat/maintenance of genetic diversity	preservation of the gene pool and endangered species	supportive

Ecosystem services selected for further analysis as compared with sustainability certification systems.

Environmental Certification of Property with BREEAM-SE

The BRE Environmental Assessment Method (BREEAM) is an environmental certification system from Great Britain, developed and administered by the British Building Research Establishment (BRE). BREEAM was launched in 1990, which makes it one of the oldest environmental certification systems. More than 250,000 buildings have been certified according to the standard, and it is the most widely-used international system in Europe (see www. BREEAM.org). The Sweden Green Building Council has adapted BREEAM to Swedish conditions and the Swedish version, BREEAM-SE, is used on the Swedish market.

An individual project's environmental performance is assessed in a number of areas. There are minimum requirements for achieving points in the following areas: environmental management of the project, the climate impact of the building, indoor climate, water management, waste management as well as land use and ecology. BREEAM also assesses and scores how a building is situated in relation to public transit and available services, choice of building materials and potential release of pollutants.

In BREEAM-SE the criteria in the landscape and ecology sections (LE 3, 4 & 6) most clearly promote ecosystem services in a project. Here, however, there are also other criteria that have a direct or indirect connection to these measures (*see Figure 2*). BREEAM-SE does not follow a time schedule as clearly as BREEAM Communities. To visualize how the different criteria could fit into a work process, a proposal was developed (*see Figure 2*). Three important steps can be distinguished in the process: the early stage, the preparation/implementation of production, and handing over to the manager. During these stages, the certification criteria relevant to ecosystem services should be considered from a holistic perspective.

Environmental Certification of City Districts with BREEAM Communities

BREEAM Communities is another system developed by BRE (Building Research Establishment). The purpose of the system is to create a framework for sustainability issues at an early planning stage. The system covers assessment and certification at a district level. There are three stages to the certification during planning: step 1 – strategies and guidelines, step 2 – the district's structure, and step 3 – design of details.

The matrix analysis shows that BREEAM Communities has several criteria linked to ecosystem services. The criteria with the clearest connection to preserving, creating and developing new ecosystem services are ecological strategy (LE 01) and green infrastructure (SE 11). There are, however, several other criteria that directly or indirectly support ecosystem services and that should be handled jointly with LE 01 and SE 11 to achieve maximum interaction between project design and the environmental certification process. *Figure 1* shows all the criteria categorised according to how they could be applied in the certification process.

BREEAM Communities has a clear schedule with a mandatory first stage. In order to realise the full potential of ecosystem services, the issues and points-based criteria should be included in a general way in the first stage, and should then feature later in the detailed design stage.

Environmental Certification of Infrastructure Projects with CEEQUAL

CEEQUAL (Civil Engineering Environmental Quality Assessment and Awards Scheme) was developed by the British trade organisation, the Institution of Civil Engineers (ICE) and was launched for use in the UK and Ireland in 2003. CEEQUAL looks at several sustainability areas, for example:

- Project strategy (optional),
- Project management,
- People and society,
- Land use and landscape,
- The historic environment,
- Ecology and biodiversity,
- Aquatic environment,
- Physical resources, and
- Transportation.

Certification can be achieved for different parts of a project and for three different stakeholders: clients, developers and contractors. CEEQUAL is the system that most clearly supports a holistic approach in-

ASSESSMENT & STRATEGY
Step 1: Strategies and guidelines

- LE 01 - Ecological strategy
- SE 03 - Flood Risk Assessment
- RE 03 - Water strategy
- RE 01 - Energy strategy
- SE 02 - Demographic needs and priorities

Sub-headings in step 2 of a general assessment.

DETAILED ECOSYSTEM QUESTIONS
Step 2: The area's structure

- LE 03 - Water pollution
- LE 04 - Enhancement of ecological value
- LE 05 - Landscape
- SE 06 - Delivery of services, facilities and amenities
- SE 07 - Public Realm
- SE 08 - Microclimate
- SE 10 - Adapting to climate change
- SE 11 - Green infrastructure

MONITOR ECOSYSTEM ISSUES
Step 3: Designing the details

- GO 04 - Community management of facilities
- RE 04 - Sustainable buildings
- RE 05 - Low impact materials
- LE 06 - Rainwater harvesting

Figure 1 Important criteria that provide a basis for analysing ecosystem services in the BREEAM Communities framework.

ASSESSMENT & STRATEGY
Analyse and Supplement at an Early Stage.

- LE 3,4 & 6 - Preserve and enhance ecological value of the site
- WAT 6 - Irrigation strategy
- FOOD 2 - Impermeable surfaces and border protection
- POL 5 - Moderating measures for minimal water runoff
- POL 6 - Sustainable urban drainage systems
- WAT 8 - Local management of waste water
- HEA 10 - Thermal comfort
- WAT 1 - Minimize the need for fresh water
- WAT 2 - Water meter
- WAT 3 - Detection of major water leaks
- WAT 4 - Shutting off sanitary water supply

WORKPLACE LOG
Monitor ecosystem service analysis during preparation and implementation of production.

- LE 6 - Workplace log for ecological protection/biological spokesperson
- MAN 3 - Best practices regarding water pollution

MANAGEMENT PLAN FOR THE SITE LANDSCAPE AND HABITAT
Monitor preservation of ecosystem services when handing over to the manager.

- LE 6 - Longterm preservation of ecological values.

Figure 2. Criteria in the BREEAM-SE framework for analysing and monitoring ecosystem services.

volving different disciplines by having points-based criteria for sustainability analyses. These criteria can apply to work with ecosystem services even though there are currently no direct references to ecosystem services in the CEEQUAL manual. To illustrate criteria that can work together from an ecosystem services perspective and that must be considered in an early sustainability analysis with the help of ecosystem services, a process has been developed for CEEQUAL in which the various criteria are brought together in a general analysis tool.

Ecosystem service assessment and ecosystem service strategy with the Biotope Area Factor as a complementary tool

As a basis for an environmental certification, as well as for work on ecosystem services in a project, it is appropriate to assess the ecological values of a site and its immediate surroundings. This type of ecological assessment, with an inventory of the number of species at a site, is currently included in various certification systems. It is during the early stages that there is greatest potential for taking a holistic view and seeing the value of interaction amongst ecosystem services. A proposal by the working group is therefore to expand the ecological inventory currently performed into an assessment in which ecosystem services are identified, analysed and evaluated at an early stage in the context of environmental certification.

A general ecosystem service assessment reveals and clarifies an area's most important ecosystem services. Such an assessment is greatly supported by other assessments which need to be carried out at this stage, especially the ecological inventory but also assessments regarding food-risk management, stormwater, local climate (sunlight conditions, wind, radiant temperatures and heat islands) and social needs (values and popular places, flaws in green structure and accessibility etc.). Below are general questions that need to be addressed in such a process.

Identify existing ecosystem services:

- Describe the ecosystem service.
- Ecosystem functions/relevance to the ecosystem service identified. How does the existing ecosystem function, and how do changes in the ecosystem influence the ecosystem service?
- Who uses/benefits from/is affected by the ecosystem service, now and in the future?
- Identify other ecosystem services affected by or connected to the identified ecosystem service (categories: supportive, provisioning, regulating and cultural ecosystem services).
- Identify whether measures need to be handled at a general level, during the planning and design of the whole city district, and/or with measures connected to individual properties or the environmental certification system.

Sensitivity and threats:

- Which ecosystem services or ecosystem functions and social values are at risk of being lost or adversely affected by the project?
- Are there conflicts/opposing interests between different ecosystem services or with other interests?

Measures to preserve or create ecosystem services:

- Make proposals for measures for protecting or strengthening existing ecosystem services and, if possible, for creating new ecosystem services.

Estimating the value of ecosystem services in the project (quantitatively, qualitatively, monetarily):

- Take into consideration how measures are connected to other ecosystem services.

Estimating the value of ecosystem services in the project (quantitatively, qualitatively, monetarily):

- What values are threatened or created by the project?
- What will be the cost and/or value added, of the project and to society?
- Valuation of existing ecosystem services.
- Valuation of new or changed ecosystem services.
- Valuation between opposing interests.
- Valuation between different scenarios.

An ecosystem service assessment can lead to a strategy for the project and for continued work. Such a strategy should address how the values will be used, which ecosystem services are important to preserve and develop, as well as which ones will be lost and how this can be compensated.

The Biotope Area Factor (BAF) directly and indirectly integrates many different ecosystem services and enables a holistic approach to planning and development that involves ecosystems, people and technology. The BAF makes it possible to measure the ecologically valuable greenery in a project both before and after construction, and it also serves as an inspiration during the process. The Biotope Area Factor is a good supplement to environmental certification.

Dealing with ecosystem service assessments and strategies requires good knowledge of ecology and the complex functions of ecosystems, as well as knowledge of the planning process and/or infrastructure and construction. Landscape architects, ecologists, biologists, and environmental scientists are examples of professionals who can work with ecosystem services - from ecosystem service assessments to structural plans and the design of city areas in the context of environmental certification. People with many different skills are needed, but documented ecological competence is a basic requirement for dealing with ecosystem services in the certification process.

ENVIRONMENTAL IMPACT ASSESSMENT
Client/planner

• 4.1.1 Site selection and 4.5.1 Impact on landscape character.

ECOLOGICAL EVALUATION
Client/planner/contractor

• 1.1.4 Environmental cost-benefit analysis.
• 4.5.3 Existing vegetation.
• 6.1.1 Land with high ecological value, 6.1.3 Ecological workplan.
• 6.3.1 Recommendations for the existing ecological elements.
• 6.4.1 Recommendations for creating new wild habitats and 6.4.2 Special structures or sections for wildlife.
• 8.10.1 Clearance and removal of existing vegetation.

CONSTRUCTION MANAGEMENT PLAN
Client/planner/contractor

• 1.1.3 b) Evaluation of social impacts and benefits and 1.2.3 Social impacts and benefits during construction.
• 3.1.2 b For example, noise dampening or light dampening measures.
• 3.3.1–3.3.2 Identification and reduction of potential effects on neighbours and planning of mitigation.
• 3.7.4 Improving beyond functional requirements, such as aesthetic values.

MASS MANAGEMENT PLAN
Client/planner/contractor

• 8.3.6 Soil management and 8.3.7 Beneficial use of surface soil.

PROJECT STRATEGY OR STRATEGY FOR ADAPTATION TO CLIMATE CHANGE
Client/planner

• 1.1.5 a) Adaptation to/conversion for climate change.

RISK ASSESSMENT, RISK VALUATION ACTION PLAN AND MONITORING PROGRAM
Client/planner/contractor

• 4.2.4 Evaluation of clean-up options including "new" technologies and 4.2.8 Prevention of pollution dispersion.

ASSESSMENT OF WATER IMPACTS AND FLOOD RISK
Client/contractor

• 4.3.1 Assessment of flood risk.
• 7.1.1 The impact on the aquatic environment.
• 7.3.1 Pollution prevention measures; 7.3.3 SUDS, 7.3.4 Management of runoff when construction is completed/infiltration, 7.3.5 Water quality during construction.
• 7.4.1 Improvement of the aquatic environment, 7.4.2 incorporation of water features, 7.4.3 Collection of runoff water for useful purposes.
• 8.6.2 Water consumption during construction, 8.6.3, water consumption during operation.

ENVIRONMENTAL MANAGEMENT SYSTEM
Client/planner/contractor

• 4.5.4 Non-vegetation elements related to the landscape.
• 4.6.1 Development proposal for landscape and 4.7.1 plan for longterm management of the landscape.

CULTURAL-HISTORICAL ASSESSMENT
Planner/entrepreneur

• 5.1.1 Basic assessment.
• 5.3.1 Listed or registered resources, 5.3.2 location of existing resources, and 5.3.5 suitable materials and specialist knowledge.

Figure 3. Proposed aggregated approach to ecosystem services in CEEQUAL in which an ecosystem service perspective could add further values through parallel consideration of other point-based criteria of relevance to ecosystem services.

The Ecosystem Service Profit Model – From Public Participation to Co-financing of Ecosystem Services

In the struggle for resources and with constrained budgets, ecosystem services often compete with other urban development interests that may seem more urgent. The report aims to show that urban ecosystem services are an investment rather than a loss or expense – an investment that can pay for itself if the economic winners and losers can be identified and brought together. The ecosystem service profit model provides a systematic and structured method for doing this that results in a financial or business model. In the Netherlands, the Gido Foundation (a joint initiative for sustainable development) has developed a method for stakeholder cooperation and co-financing for development of urban areas ("Duurzaam Rendeinstruments"). The method is based on the view that sustainability always creates value and in principle is profitable. C/O City, with the support of Gido, has developed a method for optimizing and financing ecosystem services in cities in accordance with the Swedish planning and construction process.

METHOD

The basis of the ecosystem service profit model can be summarized in three focus areas: value, users, and synergies. The goal is to find measures of ecosystem services that provide the greatest value for the largest number of stakeholders. Economic values are then used to finance ecosystem services, with stakeholders contributing according to their received added value. There are four steps in the process. In these steps, guided by a facilitator, the interested parties in an area discuss the qualities of the area, the desired values and measures, and conclude with the gains that can be created and decisions about what will be implemented.

THE ECOSYSTEM SERVICE PROFIT MODEL – PROCESS STEPS

Step 1: Stakeholders > Area qualities

The process begins with the identification and selection of the relevant stakeholders for the area. The main task in the first step of the process is to link stakeholders with qualities of the given area.

Step 2: Area qualities > Values

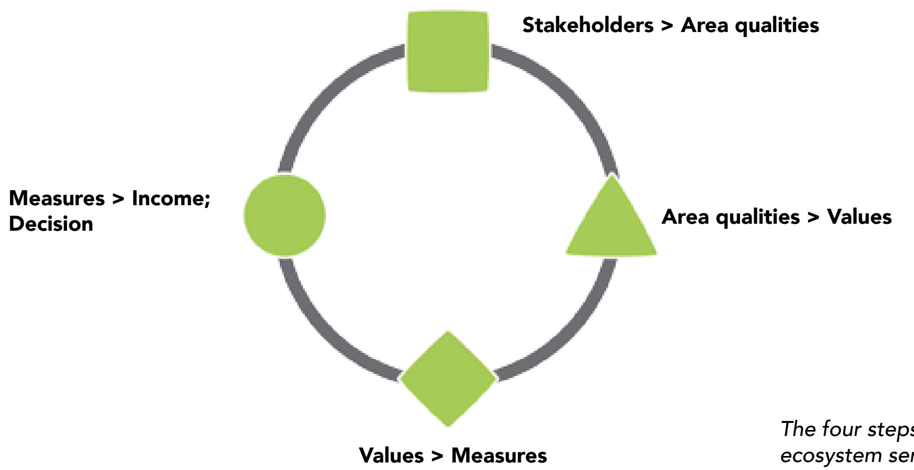
When stakeholders are identified, categorized and linked to the relevant qualities in the area, the next step is to describe the value of these qualities. This step moves from description of the characteristics to assessing the benefits of these characteristics.

Step 3: Values > Measures

Now it is time to focus on the measures. It is here that ecosystem services enter the frame. For each proposed measure, an analysis is made of (desirable) values this measure delivers and other measures it can be combined with to deliver several values simultaneously.

Step 4: Measures > Income; Decision

For the most popular (ecosystem) measures, the related cash flows of the stakeholders need to be documented. What investments are needed for these measures? What are the costs of operation and maintenance of the measures? When a suitable and feasible financing model has been developed it is time for policy makers to have their say about the cluster of measures.



The four steps that make up the ecosystem service profit model.

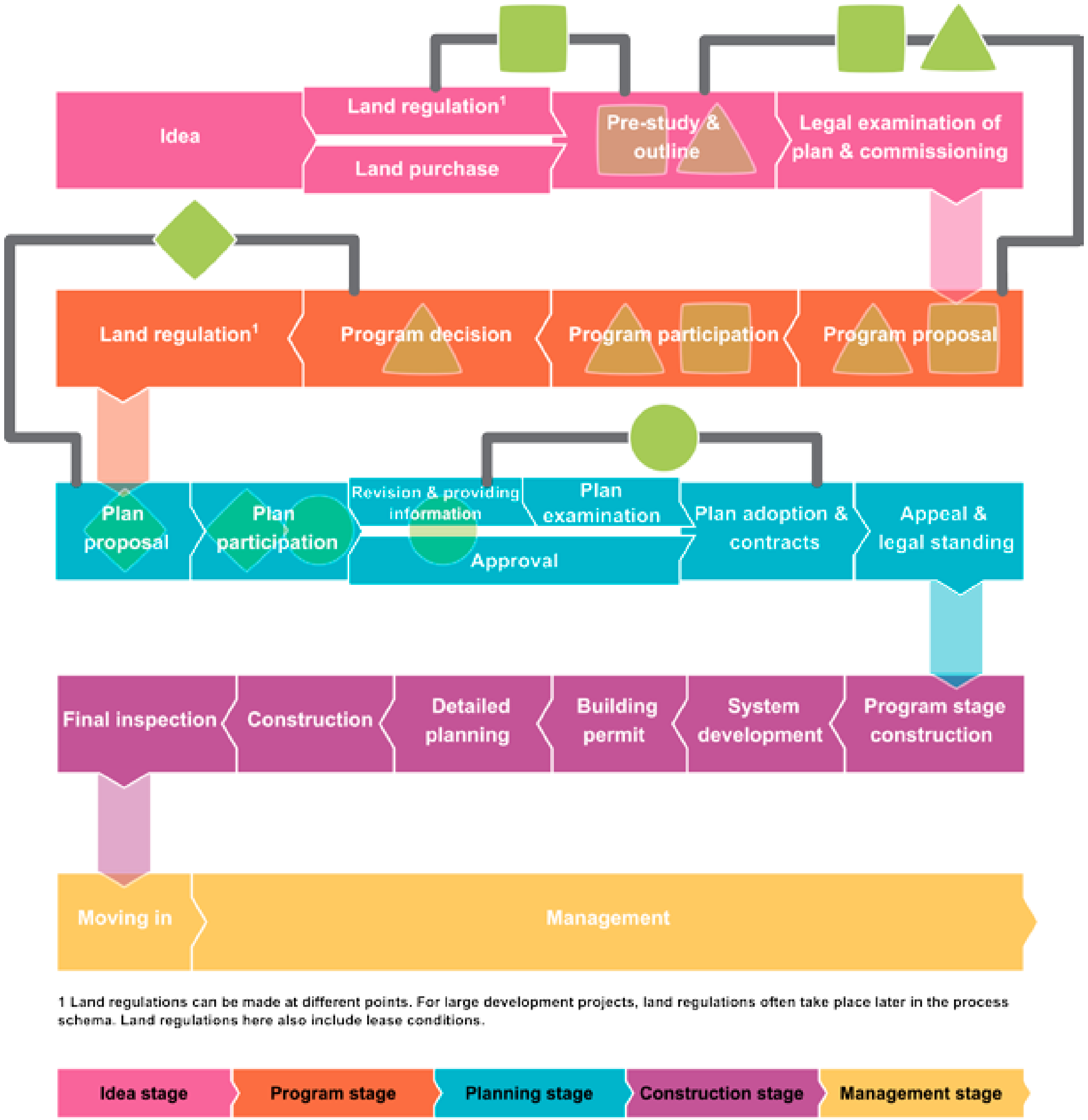
POTENTIAL

The ecosystem service profit model is a valuable addition to the planning toolbox for urban ecosystem services. Its strength is that it combines values and funding within stakeholder dialogue. The conditions for the ecosystem service profit model were improved in 2015 in the Swedish Planning and Building Act (PBL). The new PBL forces or challenges municipalities to do more of their planning in cooperation with developers and stakeholders when municipalities are forbidden from setting special technical requirements. Also contractual and financial issues must now be clarified and dealt with earlier in the planning process.

Two aspects, dialogue and financing, are at the core of the ecosystem service profit model. For the method to have an impact it is recommended that local stakeholders should be engaged early on in the process and that the benefits to them of the ecosystem service profit model are explained. Trust needs to be built up between the participating stakeholders, and funding from private parties must be handled carefully and transparently, for example with annual service charges for the values they receive from public land.

ROLE OF THE PROCESS LEADER

The ecosystem service profit model process needs direction and process management to provide optimum return. At the outset, the stakeholders in the area must be attracted to the ecosystem service profit model and be convinced that they will gain by actively participating in the process. Many stakeholders have, over time, become accustomed to working from the perspective of their own interests and costs, but this is challenged by the way of thinking and working in the ecosystem services profit model. Together with the project owners, the process manager should ensure that the right skills are used in the process. Requirements include, for example, knowledge about ecosystems, implementation of green-blue measures, and building technology, as well as economic and legal expertise in financing and business models.



Schematic description of the ideal interconnections of the ecosystem service profit model with the planning and construction process. The triangular, square and round symbols refer to the steps set out on the previous page.

COOPERATION WITH FORTALEZA, BRAZIL

Fortaleza is Brazil's fifth largest city with 2.5 million inhabitants in the municipality and a total of 3.5 million in greater Fortaleza. The city is growing very rapidly and environmental problems have increased at a similar rate. Environmental awareness in Brazil in the last 10–15 years has increased and today there is both the will to take action and the resources.

C/O CITY AND FORTALEZA

The C/O City project includes collaboration and exchange between the project partners in Sweden and the university, the construction industry, architect associations and the municipality of Fortaleza in north-eastern Brazil. One of the goals of the C/O City project is to export Swedish expertise in sustainable urban construction.

Fortaleza's City Environmental Commissioner visited Sweden in 2010 – when Stockholm was the EU Green Capital – and became interested in Swedish environmental technology, Swedish environmental expertise and work in Stockholm with the Stockholm Royal Seaport, an urban development area with an environmental profile. This led to Fortaleza's use of Stockholm's model for creating a Biotope Area Factor. There is great interest in Fortaleza in the Biotope Area Factor and certification systems. The results from C/O City have been translated and are being tested in Fortaleza. For example, one of the universities together with SP Technical Research Institute will construct a green building envelope and study how the indoor climate is affected. In Fortaleza, a development of participatory methods is taking place that is of interest to Swedish stakeholders. For example, companies, individuals or associations can adopt and take care of a tree or park. There is strong commitment for continued cooperation in which C/O City and Fortaleza together create a network and a platform for the development of ecosystem services.

The Sabiaguaba nature reserve – cooperation, local participation, biodiversity and the Biotope Area Factor

An inventory of ecosystem services in the buffer zone to the Sabiaguaba (*see map on next page*) reserve was carried out with a participatory process using the Diagnóstico Rápido Participativo (DRP) method. DRP is a fast diagnostic process involving residents, businesses, social organisations, and other local stakeholders. DRP is designed in such a way that it stimulates the participants' knowledge development during the process itself, which is also characteristic of the approach of Brazilian pedagogue Paulo Freire. DRP was carried out with 10 workshops and a large final seminar, in which all participants could share their information which was then summarized in a report. This supplemented studies by researchers at the Federal University and State University.

During the activities, three different techniques were used and as much information as possible was gathered about the area's ecosystems, their species richness and ecosystem services. It was very important that the residents were involved in the design of the technical and social aspects of the Biotope Area Factor. As a farmer who participated said: "This will not be a residential area constructed for us by experts. Here, we are involved and say how we want it to be."

People with a broad range of backgrounds participated, including young people, teachers, fishermen, and entrepreneurs in the restaurant and tourist industry, all of whom wanted to discuss the design of the Biotope Area Factor in Sabiaguaba. A specific goal of the project – which succeeded – was to reach out to many women. Eight workshops for 15 participants were held for civil servants involved in environmental administration and the municipality, to inform, educate and gather views on the Biotope Area Factor.

During two large seminars (one for two days and the other for three days), with participants from Sweden, there were 500 participants, including architects, civil servants and representatives from environmental groups, that discussed ecosystem services, the biotope area factor and city planning. Later, a network for the development of the biotope area factor and ecosystem services in Fortaleza was also created. The network includes the municipal environmental administration, the Brazilian architects' association, the Department of Geography at the Federal University (UFC), the Department of Geography at the state university (UECE), researchers from the private university Unifor, and the developers' association, Sinduscom.

Since the start of the initiative with the Biotope Area Factor in Fortaleza, hundreds of people have participated in the information and training sessions, generating important information from government officials, researchers and local residents. It was strategically important for the city to develop this methodological tool in a city district that is a nature reserve, since it was then possible to document its social, cultural, technical, practical and biological conditions. The interdisciplinary approach that assembled knowledge from the diverse fields of anthropology, culture, geography, biology etc, has proven to be successful. It provided better opportunities for preserving and protecting biodiversity, restoring the area and integrating the buffer zone with the reserve. Since demands to develop the area have been increasing, the Biotope Area Factor became an opportunity for the municipality to combine the need for new housing and infrastructure in the area with the preservation of the biodiversity of the reserve.

In Brazil, the management of nature reserves and buffer zones is distinctive as it is the responsibility not only of the public sector but also of sectors of civil society. A side effect of the work with the Biotope Area Factor has thus been the creation of a democratic decision-making structure for managing and developing a city district.

Greenery among newly built housing that replaced shanty towns in Fortaleza.

Project Vila do Mar – Background

Vila do Mar is a construction project aiming to restore nature and create infrastructure in the 5.5 km long coastal urban environment on the edge of Fortaleza in the state of Ceará, Brazil. The goal is to improve well-being for the residents of the three residential areas affected, by increasing employment, improving income opportunities and restoring green and natural areas, as well as stimulating the local culture.

The project partners are Fortaleza municipality, Caixa Economica (the state bank that finances home loans and housing policy) the national and state governments, and the Pirambu city district. For about 50 years the region along Fortaleza's east coast faced many social difficulties and was marked by violence, crime and alienation. The city district was known for its environmental problems. Local housing was poor and residents lived with insecurity and a lack of basic sanitary and hygienic provision (e.g. sewage, drinking water and electricity).

Participatory Process and Restored Ecosystem Services

A holistic perspective was central to both the initial project plan and implementation of the Vila do Mar initiative, with a focus on the basic needs of the people and of nature. In the Vila do Mar project the beach environment along a 5.5 km stretch of Fortaleza's eastern coastline was restored. Families that occupied areas in the nature reserve were able to move to new homes. Sand dunes were protected by planting native plants and were reinforced so the sand would not drift away. Information and training were given to fishermen, residents and other users of the natural environment near the ocean.

A road was built along the entire stretch of beach with bicycle and walking paths. Along the way, small streets, sewage systems, water distribution systems and sidewalks were repaired. Garbage collection, safety/security in the residential areas, access for emergency response vehicles and access to shops and services were improved. Public squares and shops along the ocean front were renovated. The entire area was made accessible to the residents. The project tried to strengthen the small-scale fishing industry in the area by providing a fish market and dock facilities. And piers were renovated to counteract erosion and restore ecosystem services near the beach.

For the 1,434 families living in the beach area, the project offered new homes at another location with better standards and access to public transport, schools, shops and other services. An additional 2,490 families were offered better living conditions with good sanitation and other basic facilities that had been missing. Playgrounds, soccer fields and basketball courts were built adjacent to the new apartment areas. The Vila do Mar project facilitated leisure activities by equipping the area with sports fields and restoring beach areas.

A museum and cultural centre for local cultural history was built, where there are exhibitions of local culture and handicrafts as well as contemporary displays and performances in various languages. ■

Shantytowns in Fortaleza. An attempt has been made to break the cycle of poverty by offering new housing nearby, with the condition that the children attend school.

New housing in a former shantytown in Fortaleza. The buildings are of good quality and there is also room for ecosystem services in the form of green areas.

After the shantytowns on the beaches were removed, walking paths were created with green spaces and excellent swimming areas along the ocean. (Photos: Fortaleza, Peter Wrenfelt)

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