GREEN SKILLS FOR CITIES

Lesson 2

Nature-based Solutions

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SECTION **ONE**

Introduction to NbS

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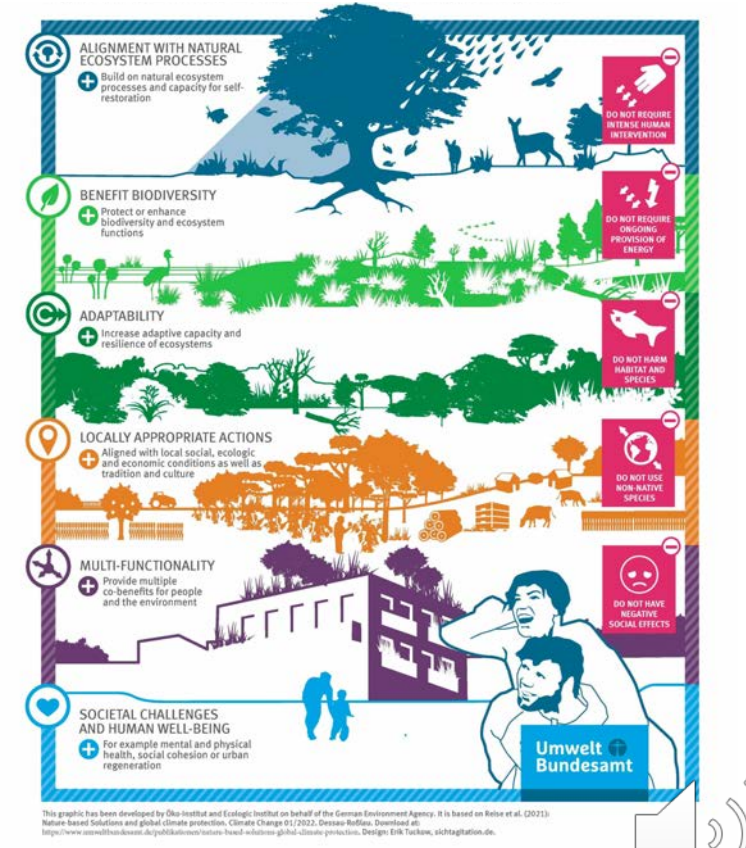
SECTION **ONE**

Introduction to NbS

For the IUCN (European Union for Conservation of Nature) NbS are actions to protect, manage or restructure ecosystems in a sustainable way, which provide benefits for human well-being and biodiversity.

Therefore, NbS address contemporary challenges such as climate change, food security, or natural disasters, and provide services to biodiversity, but also to human well-being.



GreenPlanner Ecologic.eu

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SECTION **ONE**

Introduction to NbS

NbS in Urban Design are beneficial for several reasons:

- ➔ improvement of environmental quality
- ➔ improvement of the life quality
- ➔ adaptation to climate change
- ➔ mitigation of impacts
- ➔ increase in biodiversity

All those benefits can be called "ecosystem services".

Ph. K. Perini

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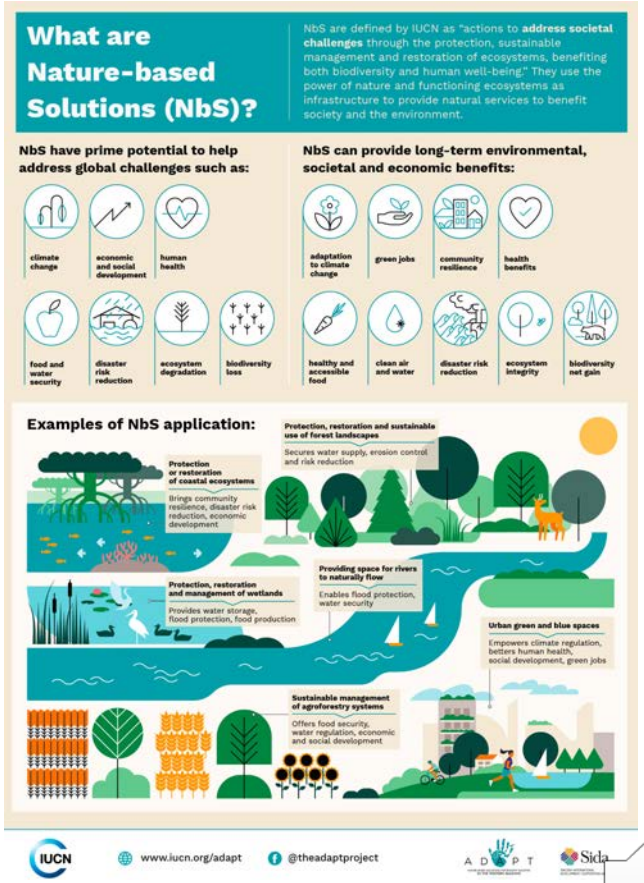
SECTION **ONE**

Introduction to NbS

Urban trees, parks and gardens intercept fine dust, absorb pollutants or lower the temperature as well as act as a buffer effect during floods. Green areas provide opportunities for recreation, improve well-being, create space for meetings.

NbS provide additional benefits, i.e. high biodiversity, species conservation, energy generation and waste management, as well as promoting social cohesion through collaborative processes.
This means that an ideal NbS is based on a co-creation of multiple environmental and social benefits.



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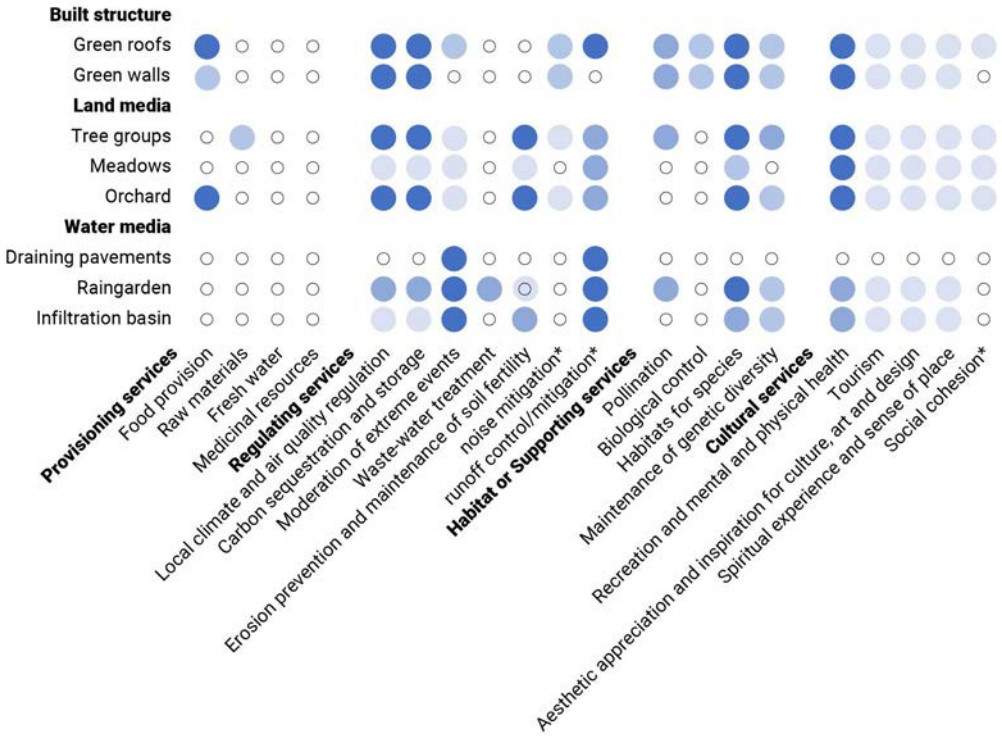
Introduction to NbS



Ecosystem services provided by Nature-based Solutions, classified according to Babí Almenar et al. (2021), for built structures according to: Coma et al. 2018; Köhler and Ksiazek-Mikenas 2018; Kotzen 2018; Palla and Gnecco 2018; Rowe 2018, Magliocco 2018; Mayrand et al. 2018; Pérez et al. 2018a 2018b, Harada and Whitlow, 2020); for land media Akbari et al. 2001; Atkins 2018; Lazzari et al. 2018; Perini et al. 2018); for water media (Ballard et al. 2007; Perini and Sabbion 2017).

The gradient of colour represents the most relevant (dark blue) to the less relevant (light blue) for each NbS.

In Perini, 2022

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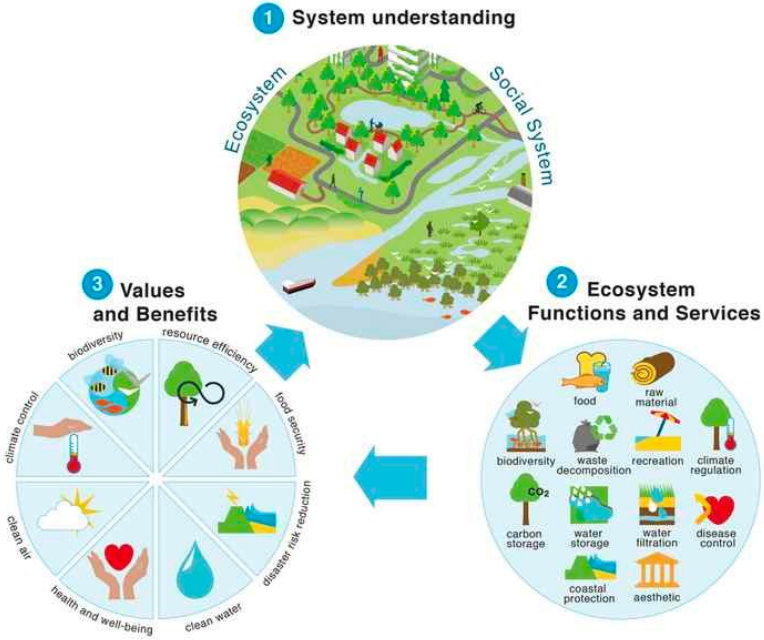
Nature-based Solutions

NbS are all those solutions that combine already existing concepts such as green infrastructure, green-blue network, ecosystem services, natural capital, ecological engineering.

This is a new concept used for some years by the EU to define solutions and interventions based on nature that provide environmental services and social benefits and at the same time help increase urban resilience.



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Nature-based Solutions

NbS: built strategies

- **Green roofs** (fig. 1)**:** living vegetation on building roofs to provide visual benefit, ecological value, enhanced building performance, reduced surface runoff. They are divided in **extensive roofs** and **intensive roofs**. (Woods Ballard et al. 2015, page 233).
- **Green façades** (fig. A,B,C): application of **climbing or hanging plants** along the wall. (Manson, Joao-Castro, 2015).
- **Living wall systems (LWS)** (fig. D,E,F): classified as continuous or modular (Manson, Joao-Castro, 2015).

Delft University Library photo credit: Nol Aders CBY-SA 3.0

Green façade and living wall schemes: K. Perini, The huge green facade of the Palace Hotel in Victoria by Green Roof Consultancy (photo A. M...co)

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NbS: land media

- **Tree groups** (fig. 1): they absorb CO_2, retain fine dust, form **large shady areas** by modifying the **microclimatic characteristics** and **increase biodiversity** (Ordóñez, C.,2019).
- **Meadows** (fig. 2): **free natural areas** hosting **insects and birds, absorbing rainwater** and **improving biodiversity** (Babì Almenar et al., 2021).
- **Orchards** (fig. 3): category of trees able to absorb CO_2 and to be a **powerful engine for increasing biodiversity. (NbS Initiative).**

Tree Library Park in Milan, photo: Luca Bruno

Wildflowers meadow, photo: Chris Gomersall

www.naturebasedsolutionsinitiative.org

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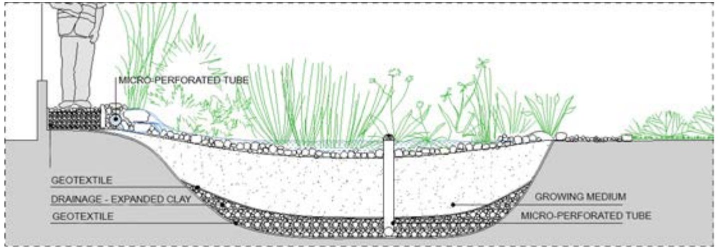
NbS: water media

- ➔ **Draining pavements** (fig. 1): pavement suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate through the surface. (Woods Ballard et al. 2015, page 387).
- ➔ **Rain garden** (fig. 3): landscaped area that collects, absorbs, and filters stormwater runoff from waterproof surfaces, sized to accommodate temporary ponding after it rains. (Rain Garden Handbook, page 3).
- ➔ **Infiltration basins** (fig. 2): flat-bottomed, shallow landscape depressions that store runoff before infiltration into the subsurface soils (Woods Ballard et al. 2015, page 258).

1. Draining pavement (photo: K. Perini)

2. Infiltration basin (photo: K. Perini)



3. Section drawing of a Rain Garden (drawing: Paola Sabbion)

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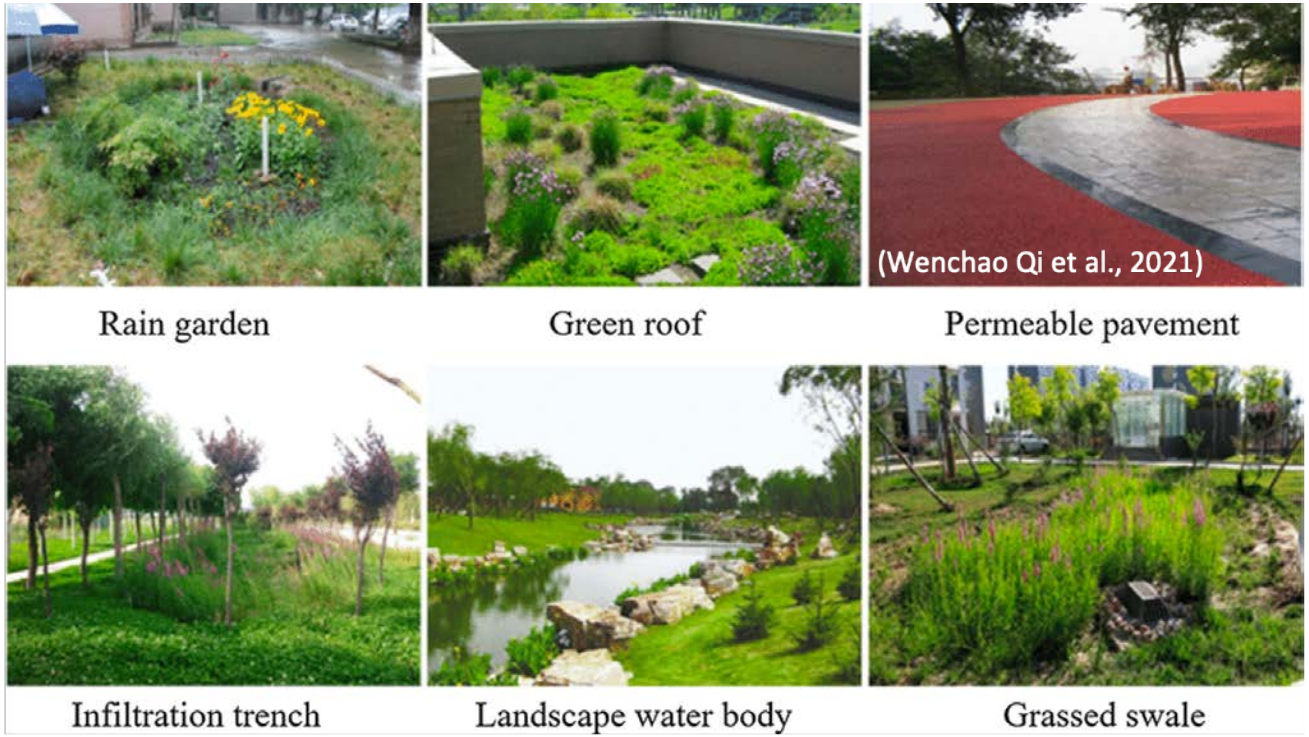

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Benefits principles: 'Why' Green Infrastructure (GI) is needed

1. Nature rich beautiful places

GI supports nature to recover and thrive everywhere, in towns, cities and countryside, conserving and enhancing natural beauty, wildlife and habitats, geology and soils, and our cultural connections with nature.

2. Active and healthy places

Green neighbourhoods, green / blue spaces and green routes support active lifestyles, community cohesion and nature connections that benefit physical and mental health and wellbeing, and quality of life. GI also helps to mitigate health risks such as urban heat stress, noise pollution, flooding and poor air quality.

3. Thriving and prosperous communities

GI helps to create prosperous communities that benefit everyone and adds value by creating high quality environments which are attractive to businesses and investors, create green jobs, support retail and high streets, and to help drive economic growth and regeneration.

4. Understanding and managing water environment

GI reduces flood risk and improves water quality by maintaining the natural water cycle and sustainable drainage at local and catchment scales; and bringing amenity and biodiversity benefits.

5. Resilient and climate positive places

GI makes places more resilient and adaptive to climate change and helps to meet zero carbon and air quality targets. GI itself should be designed to adapt to climate change.

From: Natural England

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Nature-based Solutions

Descriptive principles: 'What' good Green Infrastructure (GI) looks like

1. Multifunctional

GI should deliver a range of functions and benefits for people, nature and places, to meet their needs. Multifunctionality (delivering multiple functions from the same area of GI) is especially important in areas where provision is limited and scarce.

2. Varied

GI should comprise a variety of types and sizes of green and blue spaces, green routes and environmental features (as part of a network) that can provide a range of different functions, benefits and nature -based solutions to address specific issues and needs.

3. Connected

GI should function and connect as a living network at all scales (e.g. within sites; and across regions/ at national scale). It should enhance ecological networks and support ecosystems services, connecting provision of GI with those who need its benefits.

4. Accessible

GI should create green liveable places that enable people to experience and connect with nature, and that offer everyone, wherever they live, access to good quality parks, greenspaces and recreational walking and cycling routes that are inclusive, safe, welcoming, well-managed and accessible for all.

5. Character

GI should respond to an area's character so that it contributes to the conservation, enhancement and/or restoration of landscapes; or, in degraded areas, creates new high-quality landscapes to which local people feel connected.

From: [Natural England]

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Process principles: 'How' To do good Green Infrastructure (GI)

1. Partnerhsip and Vision

Work in partnership, and collaborate with stakeholders from the outset to co-plan, develop and deliver a vision for GI in the area. Engage a diverse and inclusive range of people and organisations including citizens, local authorities, developers, communities, green space managers, environmental, health, climate, transport and business representatives.

2. Evidence

Use scientific evidence, and good land use practices when planning and enhancing green and blue infrastructure. Understand the evidence for the benefits of current GI assets; and data on environmental, social and economic challenges and needs in the area.

3. Plan Strategically

Plan strategically and secure GI as a key asset in local strategy and policy, at all scales. Integrate and mainstream GI into environmental, social, health and economic policy. This should help to create and maintain sustainable places for current and future populations and address inequalities in GI provision and its benefits.

4. Design

Use an understanding of an area's landscape/townscape and historic character to create well-designed, beautiful and distinctive places.

5. Managed, valued and evaluated

Plan good governance, funding, management, monitoring, and evaluation of green infrastructure as a key asset from the outset and secure it for the long-term. Make the business case for GI. Engage communities in stewardship where appropriate. Celebrate success and raise awareness of GI benefits.

From: [Natural England]

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Characteristics and performances of NbS

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Characteristics and performances of NbS

During the plants' choice, there are **some aspects to consider**:

- rate of growth
- roots develop
- habit and size of the species at the adult stage
- persistence of leaves, flowering and fruiting characteristics and any unwanted elements (e.g. thorns, resins)
- robustness of the wood and the propensity to break (both of the branches and of the entire plant),
- resistance to pollutants
- resistance to pathogens and parasites
- any toxic and / or allergenic species
- frequency of maintenance (e.g. species with particular needs)

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To **maximize carbon fixation**, the following species should be favored:

- fast-growing and long-living species;
- species that reach large dimensions when ripe;
- species that are resistant to disease and to stress factors related to pollution;
- Species capable of reproducing and economically renewing the established formation
- Fast-growing pioneer species in areas of anthrosols rich in detritus or in any case of thin soils;
- Mixed species with the same management needs (irrigation, pruning, fertilization, etc)

In addition to this, the disturbance to the roots shall be reduced in order to **preserve the carbon sequestered by the soil,** which is higher than that stored by vegetation.

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Characteristics and performances of NbS

Some species to be used to maximize the CO2 sequestration:

- Poplars (the indigenous ones are Populus alba, P. nigra, P. canescens), has a rapid growth but it's potentially allergenic and requires a large amount of water;
- White willow (Salix alba): fast-growing, suitable for planting near waterways, but it can cause allergies;
- Lime trees (Tilia cordata, T. platyphyllos, T. x vulgaris): large and long-lived species;
- Maples (Acer campestre, Acer monspessulanus and A. platanoides, A. pseudoplatanus): speed of growth. A. campestre and A. monspessulanus are more rustic and adapted for interventions in pioneer and degraded conditions.

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Some species to be used to maximize the CO2 fixation:

- Turkey oak (Quercus cerris): long-lived and fast-growing;
- Lawson's cypress (Chamaecyparis lawsoniana), widely used for experimental forestation, tolerant to pollution and suitable for retaining dust;
- Hawthorn (Crataegus monogyna), rapid growth, resistant, it requires little maintenance. However, it must be taken into account that it is a shrub with thorns. Also it can be vehicle for the propagation of fire blight (caused by Erwinia amylovora), a bacterium that affects Rosaceae: its use should therefore be limited if near orchards (in some northern regions it is forbidden to plant new individuals).

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Characteristics and performances of NbS

To **mitigate acoustic and atmospheric pollution** it's necessary:

- ➔ prefer native species (that are adapted to the climate and environment in question);
- ➔ favor tree species with large and tall foliage and low maintenance requirements;
- ➔ favor long-lived, evergreen species, better if resistant to stress;
- ➔ prefer species with leaves with trichomes, waxes, resins and with rough;
- ➔ prefer leafs with irregularly shaped surfaces;
- ➔ favor low VOCs emitting species such as maple, hawthorn and lime trees;
- ➔ species less subject to collapses;
- ➔ assess the direction and intensity of the prevailing winds;
- ➔ check that the individuals are appropriately placed.

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Characteristics and performances of NbS

Some species to be used **to mitigate athomspheric and acoustic pollution:**

- Maples (Acer campestre and A. platanoides): resistant to atmospheric pollutants, as well as being efficient for the construction of sound-absorbing barriers;
- Oaks (Quercus cerris, Q. ilex, Q. robur, Q. frainetto, Q. pubescens): long-lived, large and with dense foliage, suitable for different environments and climates.
- Elms (Ulmus minor and U. montana): long-lived, tall and with dense and wide foliage, suitable for mitigating noise and atmospheric pollution.
- Lime trees (Tilia cordata, T. platyphyllos, T. x vulgaris): large and long-lived, they have dense foliage, suitable for both the mitigation of atmospheric and acoustic pollution.

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Characteristics and performances of NbS

Some species to be used <u>to mitigate athomspheric and acoustic pollution:</u>

- **Hackberry** (*Celtis australis*): long-lived, very widespread thanks to its adaptability and resistance to pollution and its thick and large foliage that generates shade;
- **Tree heather** (*Erica arborea*) and **Viburnum** (*Viburnum tinus*), evergreen, are appropriate both for the sound-absorbing function and for the abatement of airborne pollutants.

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To promote biodiversity it's suggested to favor:

- a mixture of species and of various sizes to create a more varied habitat. The stratification of natural forests can be reproduced by using suitable shrub species (e.g. Cytisus sp., Crataegus sp., Ligustrum vulgare).
- a variety of planting layouts: planting new individuals in various ways allows you to create a habitat closer to natural conditions;
- native species, to contribute to increasing plant biodiversity as well;
- species with flowers and fruits to increase pollinators, insectivorous and frugivorous species.

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Some species that can be used to <u>increase animal biodiversity</u> are:

- Hackberry (Celtis australis), which in addition to having a large crown, produces small edible fruits, with a sweetish taste, a trophic resource for various birds;
- Laurel (Laurus nobilis): evergreen that can be found both in the arboreal and shrubby state. It can be used as a refuge from fauna, and for the mitigation of noise and atmospheric pollution;
- various Rosaceae, both shrubs and fruit trees, suitable for providing trophic resources and shelter for fauna.
- Wild olive (Olea europeae), a spontaneous form of the olive tree, long-lived and rustic species, suitable for thermophilic and heliophilic conditions.

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Some other species that can be used to <u>increase biodiversity</u> are:

- Poplars: they host a rich entomofauna (Häne & Kaennel Dobbertin, 2006);
- Shrubby Fabaceae (Spartium junceum, Cytisus spp.) and woody labiates (Teucrium fruticans) are favorable to food supply by Apoidea and other arthropods;
- Aromatic species (lavender, thyme, rosemary, mint, chamomille...), especially to build hedges ornamental or delimitation (e.g. green areas, dog areas...).

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There are lots of **opportunities for integrating plant components in urban areas**.

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Characteristics and performances of NbS

Several studies underline **the interaction between humans and plants**.

From: UWaterloo.ca

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Characteristics and performances of NbS

Urban green design

Preliminary phase

- Data collection (cartography from cadastral maps, regional technical maps...);
- Systematic survey and analysis of the site (topography, mapping of non-vegetal elements and the plants, reporting of animal species, identification of points of view and panoramas, survey of elements such as roads and buildings, verification of any regulatory constraints , verification of any easements such as transit areas, chemical-physical analysis of the soil, climate, perceptual analysis of the place discovering the relationships with the surrounding landscape);
- Investigation of the characteristics of the local landscape tradition (agricultural uses, residential use of the landscape, landscape traditions, particular outdoor furnishings e.g. dry stone walls, plant furnishings, traditions linked to collective spaces, traditions linked to green spaces and gardens);
- Verification of the client's needs (through meetings or interviews, with questionnaire).

Characteristics and performances of NbS

Urban green design

Phase of drafting of preliminary and subsequent projects

The drafting must respect **simplicity and gradualness**, have a dominant motif to give a precise imprint to the green area, **respect the proportions** between green space and free space, **evaluate the harmony** of the materials used, **correctly combine colors-shapes-volumes**, it must also comply with the quality standards of systemic disservices.

Unibocconi.it

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Characteristics and performances of NbS

Urban green design

The **growth rate** can be referred to the **vertical or the diameter increase** (DBH, Diameter at Breast High) **at 1.3 m**.

It is influenced by many variables, such as soil, drainage, water and nutrient availability, light, exposure, plant age, etc.

Callipers, Forest measurement from Wikipedia, G. Elsner CC BY-SA 3.0

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Characteristics and performances of NbS

Urban green design

Plants growth it's classified into:

- Slow
- Medium
- Quick
- Very fast

Examples of **fast growing trees** :

- Mimosa (Acacia dealbata) 20 m
- Curly maple (Acer platanoides) 25 m
- Paulownia (Paulownia tomentosa) 12 m
- Red oak (Quercus rubra) 30 m
- Linden (Tilia platyphyllos, T. cordata, T. americana) 30-40 m

Specie - meter per year

Paulownia tomentosa: 5 m
Salix matsudana x alba: 4 m
Populus nigra 'italica': 3 m
Populus deltoides: 3 m
Salix babylonica: 3 m
Eucalyptus cinerea: 3 m
Platanus occidentalis: 2 m
Liriodendron tulipifera: 2 m
Populus tremuloides: 2 m
Fraxinus americana: 2 m
Acer rubrum: 2 m
Thuya standishii × plicata: 2 m
Pyrus calleryana: 1 m
Cupressocyparis x leylandii: 1 m
Metasequoia glyptostroboides: 1 m
Cupressus sempervirens: 1 m
Cryptomeria japonica: 1 m
Betula alba: 1 m

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Characteristics and performances of NbS

Urban green design

Distances of planting hedges from the border line (not considered if there is a wall)

- ➔ Hedges that grow to max 2.5m: minimum distance of 0.50m
- ➔ Hedges that grow over 2.5 m (e.g. hornbeam): minimum distance of 2 m

Legal distances of trees

- ➔ Tall trunk: at least 3 m away from the boundary line
- ➔ Not tall: at least 1.5 m away from the boundary line

Quality of the chosen plants

A correct selection of the plants is advantageous because they have a good post transplant root, they grow quickly, the chances of crashes and breakages due to adverse weather conditions are reduced, they have greater longevity.

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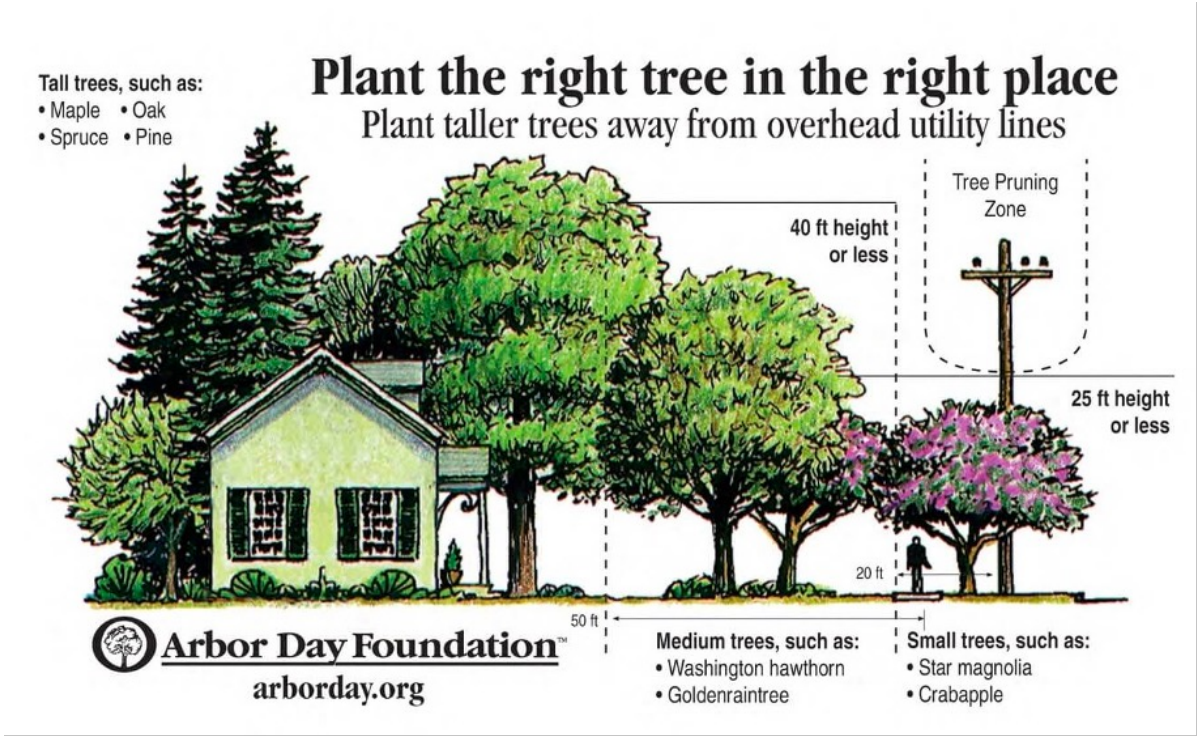
Characteristics and performances of NbS



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Characteristics and performances of NbS

Previous Eu-funded projects highlighted key barriers to the implementation of NbS in cities, which include:

- the limited knowledge base for NbS;
- the inadequate governance structures for NbS;
- the balancing of the multiple goals NbS can deliver;
- effective citizen involvement;
- insufficient social inclusion and social acceptance;
- lack of political and financial support;
- the challenges for monitoring NbS;
- the difficulties in upscaling NbS.

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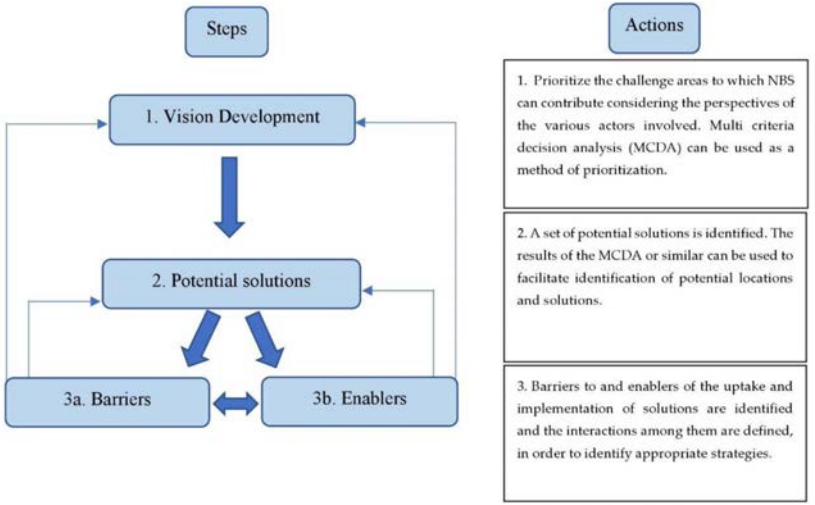
Key enablers to overcome such barriers include:

- ➔ Increase knowledge on NBS
- ➔ Engage NBS experts to support public authorities;
- ➔ Encourage participation of stakeholders and citizens;
- ➔ Guarantee political and financial support to NBS;
- ➔ Follow guidance for upscaling.



Key Enablers of and Barriers to the Uptake and Implementation of NBS in Urban Settings, in Shahryar Ershad Sarabi et al., 2019

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SECTION
FOUR

Materials and case studies

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SECTION **FOUR**

Materials and case studies

VIDEO 1

“The architectural wonder of impermanent cities”

Rahul Mehrotra

TED talks

13 min

VIDEO 2

“Urban Nature-based Solutions: What are they and why are they so important?”

WWF International

3 min

VIDEO 3

“Nature-based solutions in the fight against climate change”

Thomas Crowther

TEDxLausanne

17 min

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SECTION **FOUR**

Materials and case studies

Case studies: UNaLab

Evaluation of **NbS ecosystem services in a new urban park** (former military barrack).

Key performance Indicators evaluated:

- ➔ Biodiversity (plants and birdlife)
- ➔ Pollinator insects
- ➔ Evapotranspiration rate
- ➔ Carbon sequestration by plant
- ➔ Citizen wellbeing with environmental conditions

To obtain the benefits derived from a complex network of NbS.

www.unalab.eu

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Materials and case studies

Case studies: INPS Green Façade

INPS Green Façade is a pilot project built in the city of Genoa (Italy) in 2014 on the south wall of a four stories office building built early in the last century and renovated in the 1980s, owned by INPS (National Institute of Social Insurance).
The research results deriving from the monitoring activities are used to quantify the environmental impact for the entire life of the green facade to the obtainable environmental and microclimatic benefits, through a life cycle assessment and economic sustainability, thanks to a cost-benefit analysis.

Photo A. Ponitano

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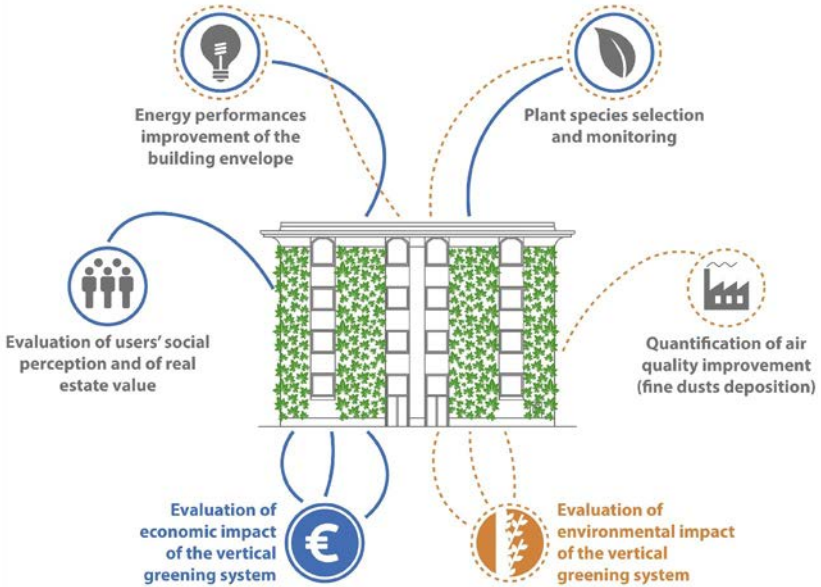
Materials and case studies

Case studies: INPS Green Façade

Video: [Facciata Verde INPS Short]

Research papers abstracts:

- Perini Katia, Ottelé Marc, Giulini Saverio, Magliocco Adriano, Roccotiello Enrica (2017). Quantification of fine dust deposition on different plants in a vertical greening system. ECOLOGICAL ENGINEERING 100 (2017) 268–276. doi:10.1016/j.ecoleng.2016.12.032
- Katia, Magrassi Fabio, Giachetta Andrea, Moreschi Luca, Gallo Michela, Del Borghi Adriana, 2021.



Monitoring activities scheme (Rosasco and Perini 201

Materials and case studies

Case studies: MosSkin

A low cost and lightweight moss envelope system for buildings has been developed to address the problem of the lack of greening in densely urbanized areas.
Several moss species have been sampled in the wild, selected, based on their ability to tolerate the abiotic stresses of urban environments and a modular multi-layer panel, with a built-in irrigation system, has been developed, designed and tested.
MosSkin is a **low-cost low maintenance, versatile and lightweight system**, with interesting performances in terms of water management and surface temperature reduction (up to 14°C).

Perini et al. 2020

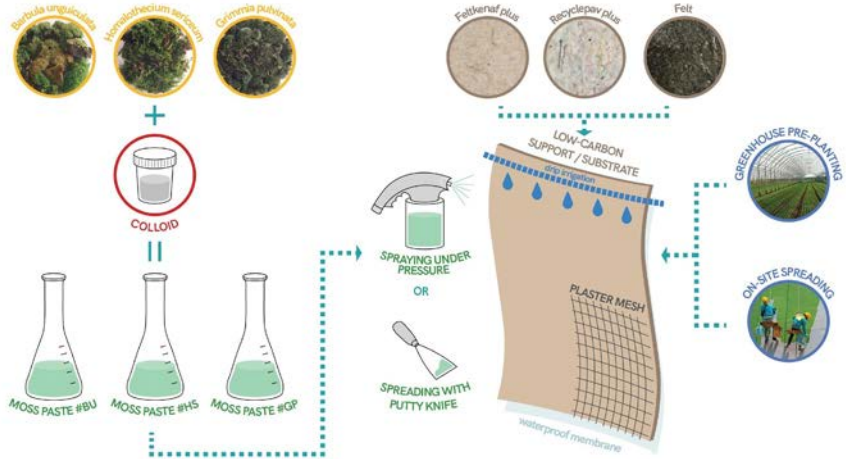
Materials and case studies

Case studies: MosSkin

Video: MosSkin

Research papers abstracts:

- K. Perini, P. Castellari, A. Giachetta, C. Turcato, and E. Roccotiello, **'Experiencing innovative biomaterials for buildings: Potentialities of mosses',** Build. Environ., vol. 172, p. 106708, Apr. 2020, doi: 10.1016/j.buildenv.2020.106708



Scheme of the patented invention

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