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Research and Innovation Action

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D1.1 – NBS multi-scalar and multi-thematic typology and associated database

Organisation name of lead contractor for this deliverable: CER		
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Document history

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Glossary

Acronym	Full name
EC	European Commission
EEA	European Environment Agency
ES	Ecosystem Services
GI	Green Infrastructure
GMO	Genetically Modified Organism
HAVC	Heat, Air Ventilation, and Cooling
IUCN	International Union for Conservation of Nature
LCZ	Local Climate Zones
N4C	Nature4Cities
NBS	Nature-based Solutions
UC	Urban Challenges
UN	United Nations
WP	Work Package
WWF	World Wide Fund for Nature

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Executive summary

This deliverable resituates the results of Task 1.1 aiming at gathering and structuring NBS knowledge.

First, the concept of “Nature-Based Solutions” (NBS) is discussed by studying other concepts already used in reference to nature. The main goal of this theoretical work is to build the framework that will be the base of Nature4Cities further developments for the application of NBS concept to the urban development context. This is described in part II.: “Definition works: introduction on the concept of NBS & scope in N4C”.

The theoretical concept has been then confronted with practical examples. A list of NBS has been compiled and for each proposal, the arguments to decide whether the case can be classified as a NBS has been discussed. In doing that, we achieved three of our goals: to confront the NBS concept with concrete cases, to build a NBS list and to build an analysis grid to read and analyse the NBS. This work is described in part III “Discussion on NBS applications – what do NBS actually look like?” and part IV “Analysis framework of the NBS”.

Part V., “NBS Classification”, relates the classification work that started form the different considerations brought by the previous developments and proposed an operational classification. This classification was built to structure the NBS inventory in a way that facilitates a recursive research in the NBS database, using operational entries. It is a mutli-thematic typology, because it is built both on the nature of the NBS and on the urban challenges to which they answer. Nature of NBS is based on the form of intervention (forms or strategies) and on the support of the NBS (water, ground or building). The typology is also multi-scalar, the NBS being classified by their scale (city, neighbourhood and entity).

Finally, having built the classification and the list of NBS, a specific work has been carried out to produce a useful documentation of NBS generic entities. The first stage was to build a common documentation grid and then examine each NBS in factsheets. This documentation process is described in the part VI “Documentation of the main NBS entities” that also gathers the NBS factsheets.

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I. Introduction

I.1 Purpose

Task 1.1 aims at gathering and structuring NBS knowledge, by defining a typology of NBS and building the associated database. The main developments are:

- to introduce the concept of "Nature-Based Solutions" (NBS) and define the framework on which Nature4Cities further developments will be based
- to build a NBS list by confronting the concept with concrete cases
- to build an analysis grid to read and analyse the NBS
- to structure a multi-thematic and multi-scalar typology of the NBS
- to document the main NBS entities

This task produced deliverable D1.1 - NBS multi-scalar and multi-thematic typology and the associated database presented in Appendix 3: NBS factsheets.

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I.2 Contribution of partners

I.2.1 Community tools

18 of the 26 partners were involved in this first task. It represents a large number of participants. In order to manage all the contributions, we used two different tools[1]:

- a blog (WordPress - https://nature4citiesblogwp1.wordpress.com/) used to discussed proposed concepts (Figure 1),
- a reference management software (Zotero) used to gather and organize literature

These tools were very helpful to favour collective reflection, to structure and capitalize the discussion. Both were more widely used in the whole WP1.

Beyond identified efforts of partners in the deliverable writing, the contents are based on the articles, the comments, etc. collectively produced on the blog.

[1] In addition, with shared documents, regular meetings, etc.

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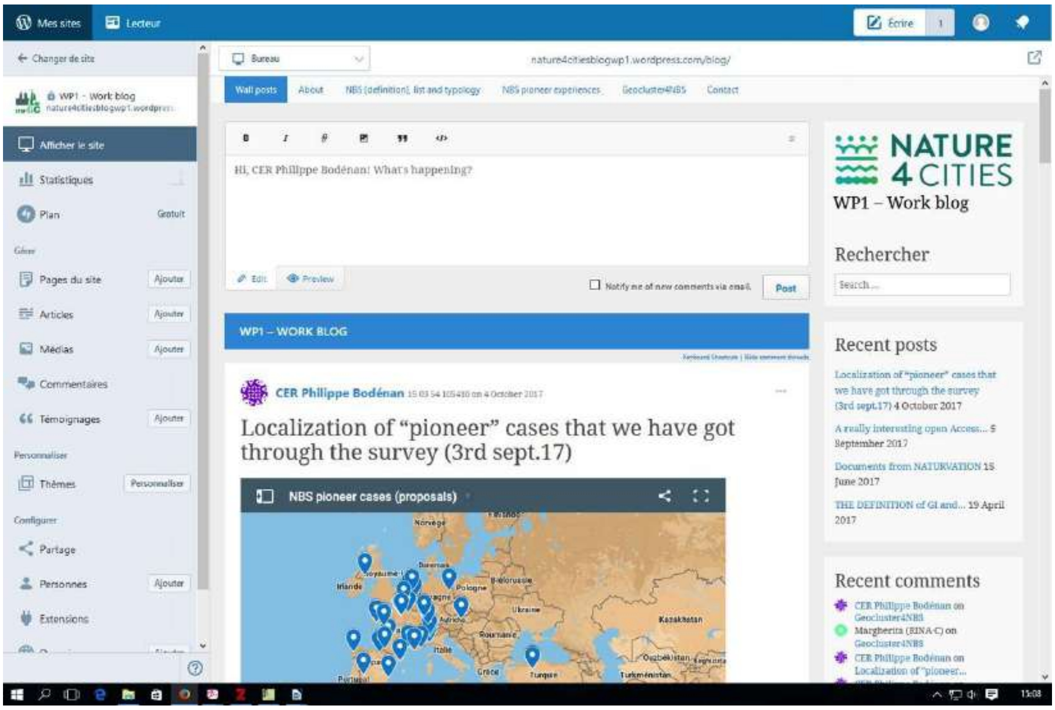

Figure 1: First page of the WP1 blog (november 2017)

I.2.2 Efforts of the partners for the writing of the deliverable (for the NBS factsheets, see next section)

Partners	Contributions
CER	Coordination of the deliverable, ToC Responsible of summary, I, II.1, II.2, II.4, III.1, III.3, IV.1, V, VI.1 Contribution to sections II.3, II.3.1, III.2.6, IV.3.3, IV.4.3, V.2.1
MUTK	Responsible of III.2.4, III.2.5, III.2.7 Contribution to sections I.3.2, V.2.1 Review of the deliverable
EKO	Contribution to section I.3.2
LIST	Contribution to sections I.3.2, II.3.2 (NBS vs ES)
G4C	Responsible of II.3.2, IV.5, Contribution to sections V.2.1
ACC	Contribution to sections V.2.1
CAR	Contribution to sections V.2.1
AO	Responsible of IV.3.1, IV.3.2, IV.4.1, IV.4.2, Contribution to section V.2.1
SZTE	Responsible of III.2, IV.2 Contribution to section V.2.1
NBK	Contribution to section V.2.1 Review of the deliverable
P&C	Contribution to sections III.2.1, III.2.2, III.2.3, V.2.1

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I.2.3 Efforts of the partners for the documentation of the main NBS (NBS factsheets)

Partners	NBS classes	NBS types
SZTE	Park and garden	- Large urban public park - Heritage garden - Botanical garden - Pocket garden/park - Green cemetery - Public urban green space (place, square, etc.) - Private garden - Wood - Lawn - Single tree
G4C	Urban network structures	- Green tram track - Street trees - Green strip - Green waterfront - Unsealed parking lot - Green parking lot
	Green walls	- Climber green wall - Green wall system - Planter green wall
		- Vegetated pergola
P&C	Urban green spaces management – Direct human interventions	- Integrated pest management - Integrated weed management - Integrated and ecological management: spatial aspects - Integrated and ecological management: time and frequency aspects - Sustainable use of fertilisers - Create and preserve habitats and shelters for biodiversity
	Monitoring	- Bio-indicators
MUTK	Protection and conservation strategies	- Limit or prevent access to an area - Limit or prevent specific uses and practices
	Urban planning strategies	- Ensure continuity with ecological network - Take into account the distribution of green spaces through the city - Planning tool to control urban expansion

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	Parks and garden	- Urban green space with specific uses (school playgrounds, campgrounds, sport field, etc.)
	Structures characterized by food and resources production	- Urban farm - Urban vineyard
	Constructed wetlands and built structures for water management	- Floodplains
NBK	Natural and semi-natural water bodies and hydrographic network	- Vegetation engineering system for riverbanks erosion control - Reopened stream
	Constructed wetlands and built structures for water management	- De-sealed area (and associated systems, ex. permeable paving) - Swale
CAR	Structures characterized by food and resources production	- Vegetable garden - Urban orchard - Urban forest
	Urban green spaces management	- Composting
	Constructed wetlands and built structures for water management	- Constructed wetland for water treatment
AO	Works on Soil	- Structural soil - Soil improvement - Mulching
	Choice of plants	- Use of pre-existing vegetation - Introduced plants - Vegetation diversification
ACC	Systems for erosion control	- Soil and slope revegetation - Strong slope revegetation
	Green roofs	- Intensive green roof - Semi-intensive green roof - Extensive green roof
CER	Ecological restoration	- Management of polluted areas by plants (phytoremediation)

I.3 Link with the rest of the N4C project

I.3.1 Link with the other tasks of the WP1

Links with the tasks 1.2 and 1.3

The NBS database is fully complementary with the NBS implementation models typology (Task 1.2) and with the NBS observatory (Task 1.3) for the development of the extensive knowledge base on NBS. The implementation model database is complementary by documenting the business models, the stakeholder networks, the barriers and enablers, etc.

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that enables the successful implementation of a NBS project. These aspects are not explored in the NBS database.

The NBS observatory is a mean to illustrate the types identified in the NBS typology with concrete examples as each case present in the observatory must refer to one or more NBS identified in the typology. The documentation of pioneer cases, also guaranties a check of the knowledge (NBS) database, by keeping a link with the most recent and innovating projects.

Links with the tasks 1.3, 1.4, 1.6 and 1.7

The NBS typology and associated database will be query through the N4C platform tools - the geocluster4NBS and the NBS pre-selection tools - respectively developed in Task 1.6 and Task 1.4.

The NBS typology is for example one of the entries of the geocluster4NBS to query the projects database. More directly, the pre-selection tool, which is a searching tool, will provide an access to the documentation on the NBS via downloadable factsheets.

By the tools respectively specified and developed in Task 1.4 and Task 1.6. The NBS database is also connected to the pioneer projects database developed in Task 1.3. These links and the deliverables where the work is described are illustrated in Figure 2.

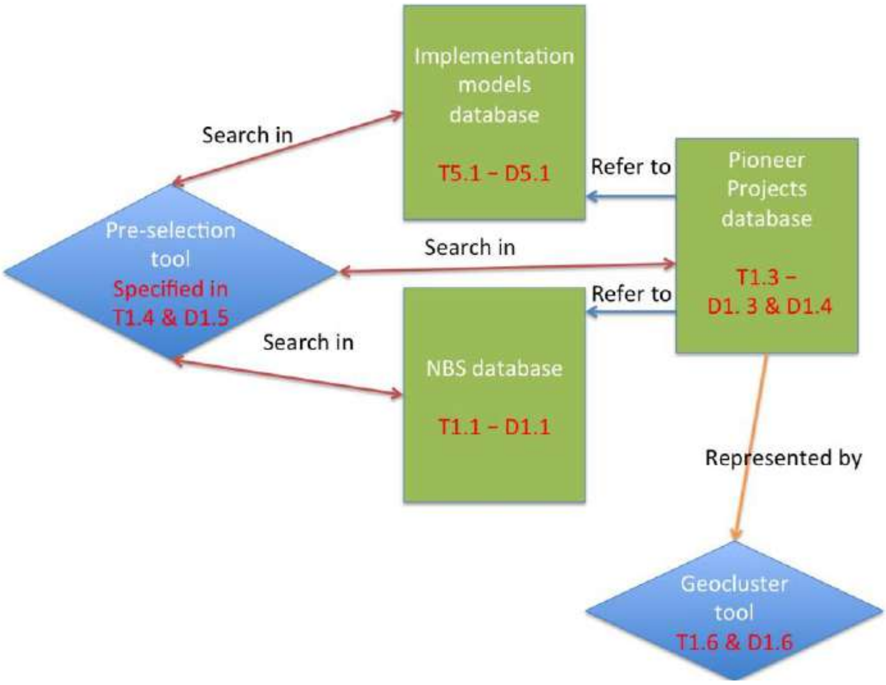

Figure 2: Links between the tools and databases developed in WP1

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I.3.2 Link with the other Wps

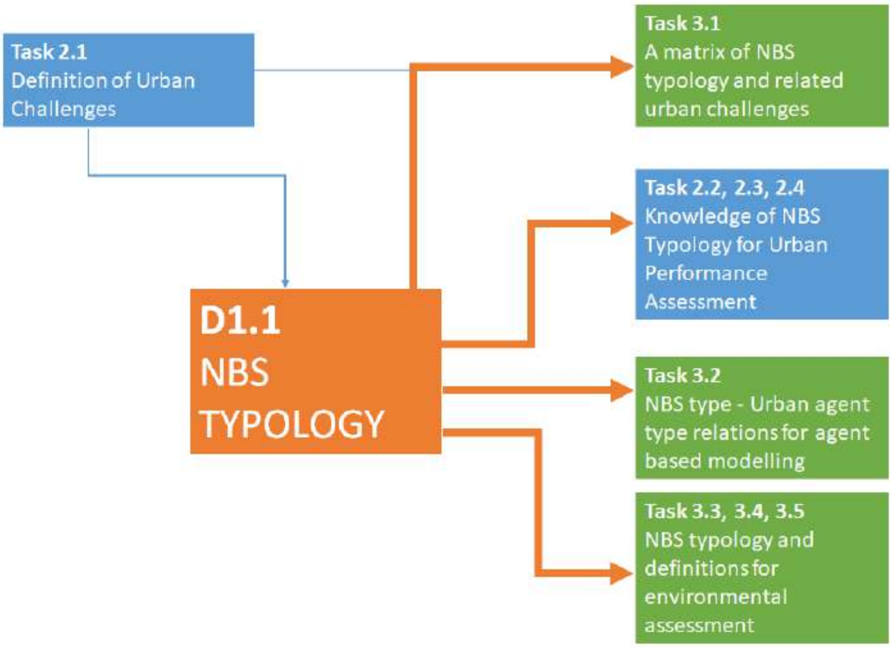

Figure 3: Tasks relation between D1.1 and other WPs (Diagram Duygu Başoğlu)

Links with WP2

Work package 2 aims to facilitate the multi-thematic performance assessment of NBS projects in order to respond to major urban challenges.
The relations between the work carried out in Task 1.1 and WP2 can be characterized on two directions. First of all, for the performance assessment of NBS, the knowledge of NBS archetypes is inevitable. This is, how D.1.1 feeds WP2 activities, Task 2.2, Task 2.3 and Task 2.4 especially (Figure 3). On other hand, the definition of urban challenges and of urban scales are both needed in the analysis framework of NBS and in the NBS performance assessment framework. This is why their development was co-leading by T1.1 and T1.2.
Regarding the further steps in the project, WP2 will provide an “expert modelling toolbox” to address performance indicators calculation on a service basis. These expert modelling tools will be applied on representative NBS projects from the NBS typology defined in WP1 in order to enrich the N4C NBS database with performance criteria.

Links with WP3

NBS typology provided from Task 1.1 is fundamental to the work of WP3, which is the environmental assessment of NBS as the starting point of the assessment methodology to be developed (Figure 3). WP3 breaks environmental assessment into three by the role of NBS in the urban metabolism (T3.1), the relations between NBS implementation and urban agents (T3.2), the impact of NBS on climate resilience (T3.4) and first establishes a thorough environmental assessment methodology (T3.3), followed by a dynamic assessment methodology (T3.5). The integration of agent based modelling into the more static urban metabolism and climate assessment works is used to achieve a dynamic assessment that provides time based results.

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T3.1 uses the NBS classification provided in this deliverable to match it with the urban challenges provided by WP2 and create a relation matrix. Through this matrix, the impact of NBS types in handling urban challenges will be studied under the scope of environmental assessment. Similarly, T3.2 matches listed NBS types in Nature4Cities project to match them with agents and narrow down to a concise list of NBS-agent relations to study. Climate assessment (T3.4) benefits from the NBS definitions provided in this deliverable. T3.3 and T3.5 are founded on these three preliminary tasks and the final assessment methodology will start with NBS classification to lead to its assessment method.

Links with WP4

WP4 quantifies social and economic benefits of NBS through the assessment of (urban) 'ecosystem services' (ES, i.e. the benefits individuals and communities can freely get from (urban) ecosystems). This is done through the adaptation of Multiscale Integrated Model of Ecosystem Services (MIMES) modelling framework to study urban NBS (Task 4.1) and the development of a monetary value scale to quantify economic cost-effectiveness of NBS (Task 4.2). The monetary value scale is complemented with a social value scale developed making use of environmental psychology methods (Task 4.3). The socio-economic assessment will be integrated in a web-based tool for automated valuation, that could be linked with N4C platform (Task 4.4).

The typology of NBS developed in Task 1.1 is used as a base for the modelling typology used in Task 4.1. The typology of Task 1.1 is adapted at Task 4.1 to be adequate for modelling purposes and to ensure compatibility with NBS solutions and ecosystem service assessments in urban and rural contexts.

I.4 General structure of the deliverable

The framework of this deliverable includes six main stages (excluding the first introductive part) (Figure 4): (I) a definition work on the NBS concept, (II) a discussion on NBS applications, (III) the construction of an analysis framework, and finally (IV) the NBS classification and the NBS documentation (VI).

The methods pursued in each stage will be explained in the course of the deliverable.

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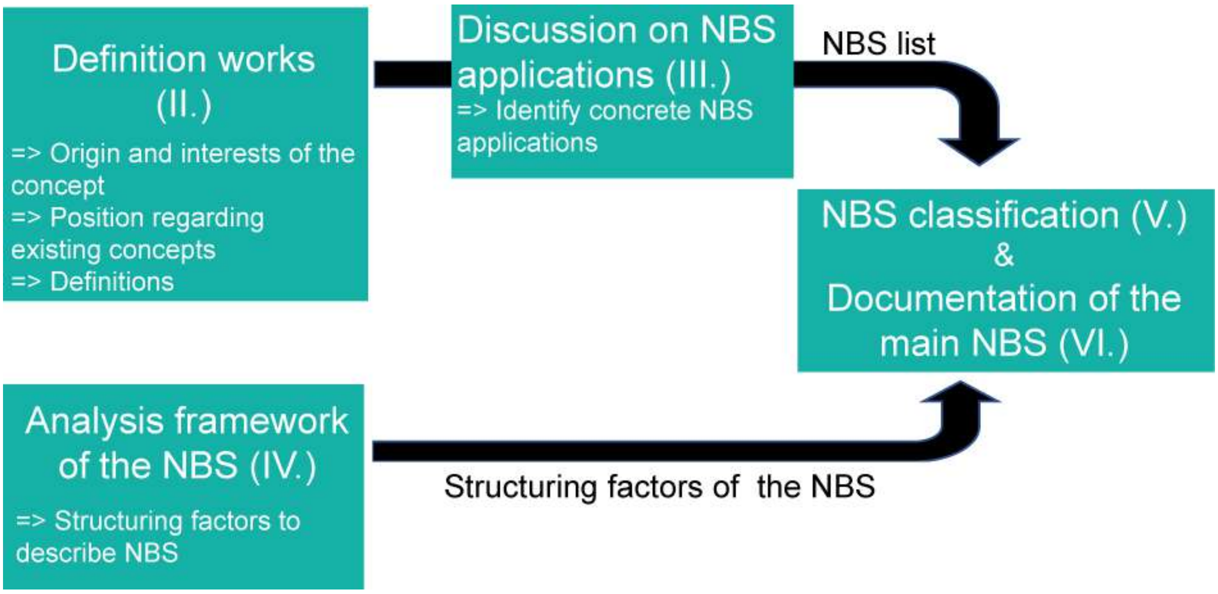

Figure 4: The 6 main stages to build the NBS typology

II. Definition works: introduction on the concept of NBS & scope in N4C

This definition stage aims to understand what the NBS concept refers to. It is a crucial stage because it is a fairly recent concept (cf. II.2.1), and the references to it are rare.
Its objective is also to better understand the definition of the NBS proposed by the EC, that we plan to re-use in N4C and apply to a particular context: the city and its development. However, another challenge was to share a common base with all partners involved in the project. It is the reason why our questionings and advances in this definition work have been presented and discussed with the WP leaders.

II.1 Definition works – method to define the NBS concept

II.1.1 Multiple definitions and interpretations co-existing: a need for a method

The "NBS" is a complex concept at the interface of multiple actors and disciplines. It necessarily generates multiple definitions and interpretations.
Three main ways can be identified to define this concept and can be associated with a specific actor:

- A possible way to interpret the concept is to build on the components of the expression "Nature Based Solutions", by breaking the term down into "nature", "nature-based" and "solutions". (Barton 2016) underlines its "self-explanatory" characteristic. It is a privileged basis for a dialogue, because it does not require prerequisites. Thus it allows non-expert people (inhabitants, politicians), scientists and experts to discuss together. However, depending on people's background, this entry generates itself multiple interpretations. The term of "nature" is especially controversial.

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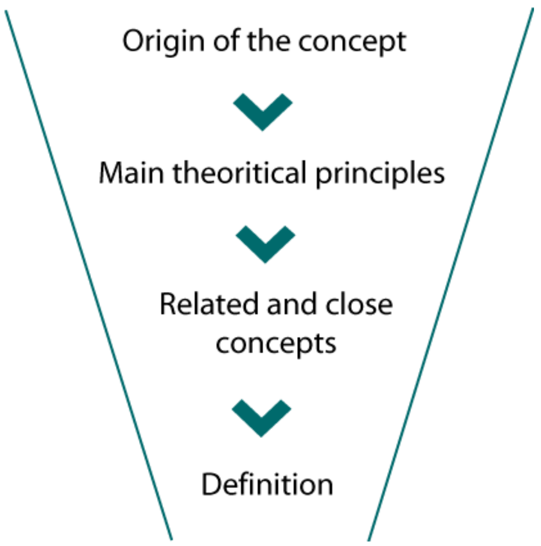
- Another way to define the NBS, is to compare it with close pre-existing concepts. What does this new concept bring in comparison with the previous ones? What are the overlapping aspects?
  This point of view is mainly developed by scientists and experts who already have a good knowledge of the pre-existing concepts. This entry provides the outline of the concept, but it does not allow to define its core. We developed this entry in the previous section II.3 Relation with pre-existing neighbour concepts.
- Institutions –as the EC or the IUCN for example- also proposed more precise interpretations of the concept. Beyond NBS principles, these definitions are already oriented interpretations. They fit with frames of application of these institutions and with their political position.
  See (Cohen-Shacham et al. 2016) for a comparison of the definitions of the EC and the IUCN. In N4C, we are starting from the EC definition that is developed in the next section.

These three entries bring a new look at the NBS concept. Unfortunately, they often co-exist confusedly. We propose to structure them to get a more general and clear overview.

II.1.2 Method implemented in N4C to define the NBS concept

The definition works are based on literature review. Four definition stages have been developed in this review:



The context (period, actors, fields) in which this new concept has emerged.
The main principles that define NBS. They are especially useful to understand the "spirit" and interest of the concept. Their advantage is to be broader than definitions and therefore they are more widely shared.
The links with related and close concepts. It aims to: ⇨ Place this concept in a general conceptual framework ⇨ Explicit the innovativeness of the main theoretical principles of overview of the concept in comparison with pre-existing neighbour concepts
NBS definitions It is important to show that different definitions of the NBS are currently co-existing. Then, this stage aims to clarify the NBS definition of the European Commission, which is also the scope of the N4C project.

II.2 Origin and principles of the concept

II.2.1 A recent and still under construction concept

The "NBS" is a recent environmental concept which evolves according to a chronology

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defined in Figure 5. According to (Potschin et al. 2016), the term firstly appeared in the 2000s. It roots simultaneously in the agricultural context and in the industrial design.
The term was mentioned or suggested at this period, but one of the first attempts of definition was made by the IUCN in its *2013-2016 programme* (IUCN 2012). We can note that initially the terms of "Natural solutions" and "Nature-based Solutions" were both used.
From the early 2010s, the term is more widely used. From that moment, the concept has been linked with topics dealing with climate change and biodiversity. The World Bank and the IUCN are key actors in the widespread of the term.
The NBS were not especially defined in the urban context at the beginning. Even if the UN referred to the potential advantages of NBS in urban planning (United Nations 2013), this is the EC and its programme for research and innovation 'Horizon 2020' that clearly focus on this aspect.
Despite all these successive stages, the concept is not well defined yet and still evolving (Nesshöver et al. 2017; Schaubroek 2017; Albert, Spangenberg, and Schröter 2017).

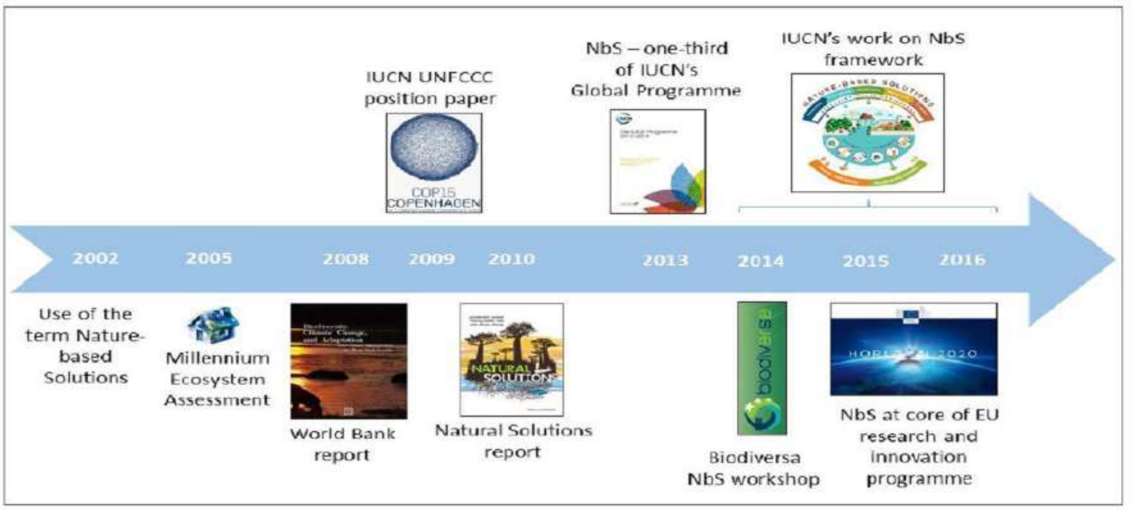

Figure 5: Timeline of the NBS concept (Cohen-Shacham et al. 2016)

II.2.2 Main theoretical principles for an overview of the concept

Currently, the multiple definitions and interpretations (they will be explored in the rest of part III.) make the concept not easy to depict. That is why, it is important to set a first overview of the concept. A review of literature makes clear that some principles are redundant.

Main principles of the NBS		References
A systemic Approach	● Multiple challenges simultaneously addressed: environment, social and economy They are especially adapted to new and complex purposes: biodiversity loss, climate change, more frequent natural disasters and rapid urbanisation. ● Multiple and interconnected spatial and temporal scales - NBS are thought at a general level and are adapted to the local context. - Solutions are thought in a temporal dimension and they	(Keesstra et al. 2018) (Albert, Spangenberg, and Schröter 2017; Nesshöver et al. 2017; Eggermont et al. 2015) (European Commission 2015)

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	are ideally resilient to changes. ● A shared concept -from its origin- between scientists, politicians and practitioners	(Nesshöver et al. 2017)
An operational concept	● A necessary positive response. The concept is centred on societal challenges. It is a “human–centred utilitarian concept” ● Compatible with technology and human intervention “NBS are actions”: protection – restoration – management (IUCN) + design of new ecosystems (EU) ● The term of “solution implies a proactivity or at least an intentionality”. It is a clear difference for example with GI (see II.3.2, b.) that includes for example all natural elements even if they are not voluntary (for example the waste lands). ● NBS are cost-effective. It means that they are rational solutions from the economic point of view (NBS cannot be limited to environmental militant solutions. They have an economic interest). ● NBS imply political choices (trade-off). It is a consequence of the multiple challenges addressed. The challenges must be hierarchized and compromised must be found. It is at the opposite of sectorial solutions, which calculate an optimum for a given challenge. ● NBS concept is compatible and complements pre-existing neighbour concepts such as Ecosystem Services, Green Infrastructure, Sustainable Urban Development, etc.	(Potschin et al. 2016), (Eggermont et al. 2015) (Cohen-Shacham et al. 2016; European Commission 2015) (Cohen-Shacham et al. 2016) (Eggermont et al. 2015; European Commission 2015)
Link with natural features	● NBS are based on ecosystems (or/ and) are “living solutions” ● NBS use physical features and processes of nature.	(Cohen-Shacham et al. 2016) / (European Commission 2015)
The concept is built in opposition to/ as an alternative to:	● “technological strategies, which are designed and managed to be as simple, replicable and predictable as possible” ● “artificial, man-made and high maintenances strategies, which are costly and usually not successful over a longer period of time” ● “the human and industrial [solutions]” It refers to man-made and artificial constructions and also to standardized industrial solutions.	(Eggermont et al. 2015) (Keesstra et al. 2018) (Schaubroek 2017)

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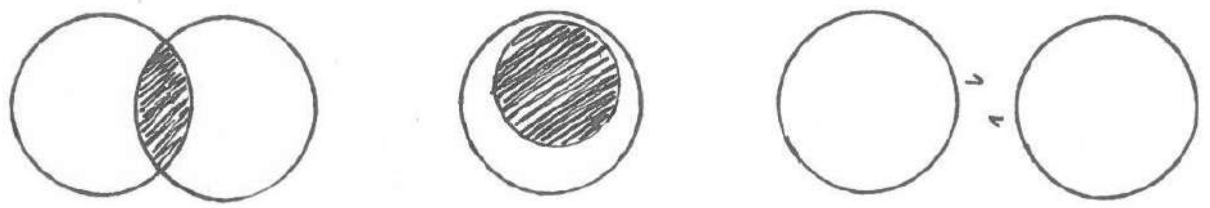
II.3 Relation with pre-existing neighbour concepts

The literature unanimously (Editorial Nature 2017; Nesshöver et al. 2017; Cohen-Shacham et al. 2016, etc.) links the NBS with several pre-existing neighbour concepts currently used in the environmental sciences and related both to sustainable development and nature conservation.

However, this relation with pre-existing neighbour concepts has to be more enlightened. This section first aims to clarify the concepts involved, then to define what connect them. For this last point, we will focus on 3 kinds of relation (Figure 6):

- overlapping: when two concepts have common parts and differences,
- encompassing : when a concept fully includes (or is included by) another concept
- complementarity: when two concepts have no intersection but present a complementarity.



Overlapping (and differences)	Encompassing (and scope differences)	Complementarity between concepts

Figure 6: Discrimination of the possible relations with neighbour concepts

There is a dual interest to develop the understanding of the relation between the NBS and the related concepts:

- to develop a better understanding of the NBS concept itself. It is rooted in previous concept and, as underlined by (Maes and Jacobs 2015), it is very valuable for our project to capitalize on these already advanced knowledge
- to understand the place of this concept in a more general conceptual framework.

II.3.1 An overview of the relation with pre-existing concepts: a review of literature

This section aims to dress an inventory[2] of these neighbour environmental concepts according to four references. Indeed, if certain concepts are redundant, depending on reference, the identified related concepts list is not necessarily the same and it can be more or less extended.

The editorial of the Nature review (Editorial Nature 2017) sets the recent NBS concept in the broader context of the pre-existing concepts in the environmental sciences (also called "natural language" in the editorial). Three concepts are identified:

- Ecosystem services
- Green-blue infrastructures
- Natural capital

Nesshöver et al. (2017) propose a list of related concepts, close in many ways but that cannot be merged. This article compares the definitions and identifies the "potential relation to NBS". Here are the listed concepts:

[2] Please refer to the original references to get a definition for each related concept.

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- Ecological Engineering and Catchment Systems Engineering
- Green/Blue infrastructures
- Ecosystem Approach
- Ecosystem-based Adaptation/Mitigation
- Ecosystem Services Approach/Framework
- Natural Capital

The IUCN (Cohen-Shacham et al. 2016) also underlines a filiation with pre-existing concepts:

- Ecosystem restoration approaches
    - Ecological restoration
    - Ecological engineering
    - Forest landscape restoration
- Issue-specific ecosystem-related approaches
    - Ecosystem-based adaptation
    - Ecosystem-based mitigation
    - Climate adaptation services
    - Ecosystem-based disaster risk reduction
- Infrastructure-related approaches
    - Natural infrastructure
    - Green infrastructure
- Ecosystem-based management approaches
    - Integrated coastal zone management
    - Integrated water resources management
- Ecosystem protection approaches
    - Area-based conservation approaches including protected area management

Potschin et al. (2016) explains the links between several environmental concepts:

- Natural capital
- Ecosystem services
- Nature-based interventions
- Ecosystem-based solutions
- Ecosystem-based adaptation

Globally to these four references, two main families of neighbour concepts can be distinguished:

- Ecosystem-related concepts.
  NBS is often described as an "umbrella" concept for these concepts (Cohen-Shacham et al. 2016; Albert, Spangenberg, and Schröter 2017) because they are encompassed by NBS.
- Other environmental concepts.
  These ones are often larger than ecosystem-related concepts. They include or overlap the NBS.

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II.3.2 Comparison between NBS and 3 neighbour concepts

In N4C, we especially discussed the connections and differences with three neighbour concepts: (a) Ecosystem Services (ES), (b) Green Infrastructure (GI) and (c) Sustainable Urban Development. Focusing on these three concepts helps to explore the nature of their relation in-depth.
These three concepts are especially interesting. Indeed, “ES” and “GI” are ones of the most commonly environmental terms employed, encompassing the sustainable development and nature conservation. On its side, the “Sustainable urban development”, even if it not cited as neighbour concept of the NBS, is a concept that focus on the urban context, which is one of the specific purpose of N4C.

a) NBS versus ecosystem services (ES)

The Ecosystem Approach (EA) has increased in importance since its approval at the 5th Conference of the Parties of the Convention on Biological Diversity in Nairobi in 2000. In particular, the 5th principle: maintenance of ES throughout the conservation of the ecosystem structure and functioning, has become highly relevant. From its origins, ES has been seen by environmental scientists as valuable to show the importance of the maintenance of ecosystems (Frank et al. 2012) and relate their conservation to the maintenance of human well-being. The current relevance of ES might have been also influenced by the release of the Millenium Ecosystem Assessment (Millenium Ecosystem Assessment 2003, 2005) and its integration as a main research topic of ecological economics through the work of well-known scholars such as Costanza (Costanza et al. 1997; Costanza 2008; Costanza and Kubiszewski 2012) or (Wallace 2007) and their discussions about ES classifications and the need or not to consider intermediate services. In the last decade, ES became a central topic in conservation biology and environmental assessment research, and intermediate ES started to be let out of the latest classifications (e.g. Common International Classification of Ecosystem Services) to avoid double counting issues. Nowadays, the study of ES is expanding to the study of urban areas (Zardo et al. 2017; Geneletti and Zardo 2016; Maes et al. 2016) being introduced as part of urban assessments and informing urban planning. But also, some scholars are starting to point out the need to consider Ecosystem Disservices (EDS), the negative impacts to human well-being derived from ecosystems (Shackleton et al. 2016; Schaubroek 2017), together with ES.

Additionally, several scholars have related the concept of ES to the one of NBS, since the origin of the latter with more or less emphasis (Maes & Jacobs 2015; Eggermont et al 2015; EC 2015, IUCN 2016, Potschin et al 2016; Nesshöver et al 2017). However, even if the concepts are related they are not equivalent.

In the words of Maes & Jacobs (2015) NBS *as any transition to a use of ecosystem services with decreased input of non-renewable natural capital and increased investment in renewable natural processes*. Eggermont et al (2015) go further and propose three conceptual types of NBS organised taking into account their contribution to an increased provision of ecosystem services and the level of engineering to be applied (Eggermont et al 2015, IUCN 2016). Moreover, as stated by IUCN (2016) and EU (2015), NBS could be actions to maintain and enhance the flow of services produced by them. Hence, from this perspective NBS could aid to operationalise the concept of ES (Potschin et al 2016).

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In addition, NBSs need to be defined as actions or structures with specific properties/attributes that permit its differentiation from other NBS. Those actions/structures should be characterised as specific or tangible responses (solutions) to one or more challenges (in the case of N4C urban ones). The implementation of those actions increase (but also could decrease) the provision of certain ES, which as mentioned before are the output obtained from NBS, but are not the ES themselves. For example, many types of NBS (e.g. grass filter strips, land management techniques to keep the understory of productive woodlands, retention ponds, bioswales) could enhance flood alleviation. But they are not the flood alleviation service themselves, this is just one of their outputs. In fact, NBS usually would offer more than one ES, and these may relate to more than one challenge or NBS.

Moreover, NBS could contribute to the enhancement/provision of different ecosystem services in different grades of intensity (Figure 7), and those ES could also contribute to solve different urban challenges more or less effectively. Actually, how you design and implement an NBS and the specific cultural/biophysical factors and barriers of its context may have an effect on the supply of ES. In other words, the surrounding physical and socio-ecological context itself is a relevant factor in the relation between NBS and ES.

Therefore, ES represent some of the positive outcomes produced or enhanced by NBS which are influenced by the context, but ES are not the solution themselves.

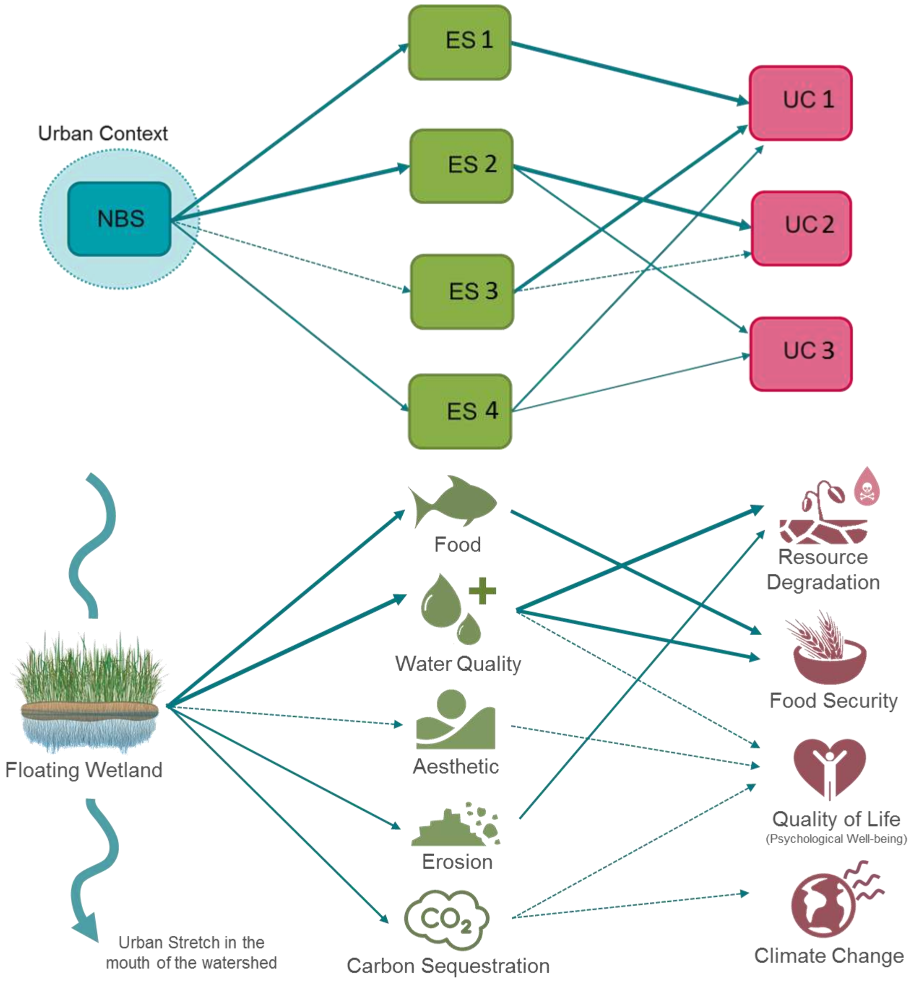

Figure 7: Relation NBS-ES and urban challenges (UC) and illustrative example (Diagrams: Javier Babi Almenar)

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b) NBS versus Green Infrastructure (GI)

The difference between those two concepts appears to be subtler than with respect to ES and it depends on the disciplinary perspective used to define each concept, where the boundaries are placed, and maybe which concept incorporates the other.

GI can be defined "as an interconnected network of any natural, semi-natural, and man-made green and blue features" (European Commission 2013, Nesshover et al. 2017). Similarly, to NBS, GI also provides social, economic and ecological benefits, but more on a strategic level. As Nesshover et al. (2017) suggests, the emphasis here is in the term "infrastructure" like in transport infrastructure or electric infrastructure. Therefore, the relation or connectivity between elements is relevant for GI concept. Instead, the NBS definition do not have the "network/infrastructure" connotation.

GI could include "any natural" element, and NBS is about "nature-based" which is more than an element based on nature (inside a gradient nature-technology). Therefore, in some cases, existing natural systems (e.g primary forests) could be part of a GI, but are not necessarily considered NBS since they were existing "natural solutions" with no human action and are not solutions based or inspired in nature.
Since NBS do not have the network connotation, in some cases it is difficult to talk about NBS from a strategic perspective, despite IUCN (2016) considers as one of the criteria the landscape level when defining NBS. In this sense, it is still a very loose concept at broad scales and difficult to differentiate from natural elements in some rural contexts. This does not seem to be a limitation of GI.

Therefore, NBS could be considered as a concept integrated inside GI (Figure 8). For example, GI could include elements such as ecoducts or tunnels for animals, but this will not be part of NBS, since is not a living solution. However, several scholars consider the opposite situation and understand GI as a concept under the umbrella of NBS (e.g. Pauleit et al 2017).

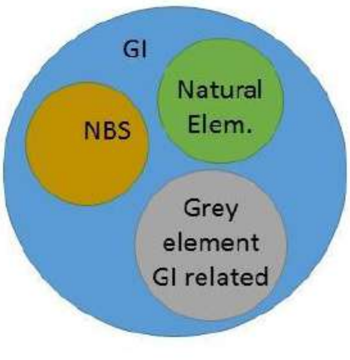

Figure 8: GI, an integrating concept that includes NBS (Diagram: Jabier Babi Almenar)

c) NBS versus sustainable urban development

Urban development in general has a very long history due to settlements of people. Also the term sustainability, coming originally from forestry, got more and more trendy in the last years. In the 1970s this two terms were combined together to a concept which has been applied by urban planners and architects only since 1990s. In times of global warming sustainable development got an important issue in urban planning (WHEELER et al., 2014).

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In the year 2015 the UN has published the 2030 Agenda for Sustainable Development which is "a plan of action for people, planet and prosperity" (UN, 2015). This universal acknowledged and committed agenda contains 17 Sustainable Development Goals and 169 related targets, but with no specific related context to urban areas (Figure 9).

Figure 9: UN Sustainable Development Goals (UN 2015)

The EU commission has made several commitments to contribute to the UN 2030 Agenda for Sustainable Development (Figure 10) and they also set up the New Urban Agenda for the EU including different action plans, thereunder the URBACT network (EU Commission, 2017).

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Figure 10: Urban Agenda for the EU (EU Commission, 2017)

The Sustainable Urban Development concept seems to be much wider than NBS. Because it considers all the sustainable solutions that address human needs in the urban context including buildings, transportation (and other) networks, mixed strategy, etc. (see Figure 7 and Figure 8) and not only the nature-based ones.

Because this concept is mainly used by urban actors, the ecological challenges taken into consideration are restricted to the produced urban frameworks even if drown within many other challenges.

To conclude, in an urban context, NBSs can be a part of sustainable urban development solutions as they answering not only to ecological challenges but also contributing to different other challenges, among other measures that designers can take.

II.4 NBS definitions

Trace the origin of the concept, clarify its principles or its innovativeness in comparison with pre-existing concepts are necessary stages to understand the concept of "NBS".

But the last stage of these definition works is the formulation of a definition that helps to precisely provide the limit and the content of the NBS.

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II.4.1 A self-explanatory concept?

Defining the NBS concept by building on the components of the expression "Nature Based Solutions", by breaking the term down into "nature", "nature-based" and "solutions". (Barton 2016) underlines its "self-explanatory" characteristic at the opposite of the ES or GI concepts, which appear as more technical terms.

Moreover, as emphasised before, this first way of interpretation offers a privileged entry for non-expert people (inhabitants, politicians) because it does not require prerequisites. However, depending on people's background, this entry generates itself multiple interpretations:

- "Nature": the term has different meanings considering the discipline/background of people. From the point of view of biologic sciences, it relates to biodiversity (declined at different scales, from species to ecosystems). But for the earth sciences, it also includes the physical abiotic elements. Another highly discussed factor of this concept is the degree of human influence accepted to keep the character "natural".
- "Nature-based": it is the utilisation of elements of nature. Once again, this expression is highly debatable. There are two main readings. For some, solutions have to be physically based on elements of nature (ecosystems). Whereas for other, they can be based (copied, inspired) on principles, processes observed in nature and, then translated in artificial mechanic and chemical processes (some cases of biomimicry).
- "Solutions": refers to the answer to a specific problem (further express as challenge). This term seems to be the more unequivocal. It refers to the operational character of the concept.

In conclusion, this entry enables a first approach of the concept and is a good support for a discussion. But, its vagueness does not lead to a real definition.

II.4.2 The NBS definition of the European Commission

In N4C, we based our work on the NBS definition proposed by the EC. However, we note that some slight variations go around between different EC definitions:

> "Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, [...] Nature-based solutions use the features and complex system processes of nature, [...] These nature-based solutions ideally are resilient to change, as well as energy and resource efficient, but in order to achieve these criteria, they must be adapted to local conditions." (European Commission 2015) (The extended definition is in Appendix 1: Definition of Nature-based Solutions by the European Commission (2015))

> "Nature-based solutions to societal challenges are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such

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solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions." (European Commission 2017)

"as living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits" EC in (Maes and Jacobs 2015)

The EC definition of the NBS: one or several definitions?
These variations do not reflect contradictions or changes in the definition but they precise different aspects of the definition.
Below, we only explicit two aspects, which can be considered confusing:

- The influence of the biomimicry concept[3]

The EC definition tackles at multiple times, the notion of biomimicry: solutions "inspired" and "copied from nature". A cited example of NBS is "mimicking how non-human organisms and communities cope with environmental extremes."
The two concepts have in common a deep understanding of nature functioning and processes. NBS and biomimicry are also both compatible with human interventions and the utilization of technologies.
However, NBS cannot be totally merged into biomimicry. In the EC definition, NBS are defined as "living solutions", but it is not the case of all the solutions based on biomimicry. Some of them are physically based on abiotic and man-made systems. One of the most used example to describe the biomimicry concept is the *Velcro* fasteners. It is inspired from the burrs (*Arctium*). The heads of these plants have the particularity of easily catching animal furs and, clothes. But, applied to the textile industry, the system is not based on plants (living materials) but on synthetic fibres.

- The influence of the ecosystems – how to understand "nature-based"?

The NBS definition of the EC, is in line with the ecosystem services concept. Thus, it provides a wide importance to ecosystems and the presence of life. The advantage to be physically based on natural elements, is to benefit from the natural flows of matter and energy (Keesstra et al. 2018), and also to benefit from the malleability (capacity to evolve and therefore to adapt) of nature. It is expecting to get more resilient solutions. Another important advantage is to contribute to the urban biodiversity.
At the difference of the IUCN, why does the EC definition favour the notion of "living" over "ecosystems" ? In N4C, we are not at the origin of this choice, but it makes sense from our point of view. Indeed, the term "living" is a bit broader than "ecosystem". This could integrate the fact that it is more complicated to maintain complex and functional ecosystems in urban context (on which the EC definition especially focuses, rather than the IUCN one) than in natural and semi-natural areas (on which the IUCN definition focuses). Thus, "living solutions" can be considered as a first stage– and meanwhile interesting one- toward more natural features in city.

The EC definition also clarifies its position, on solutions that could be at the limits. It clearly

[3] The concept of biomimicry must be here connected with concepts such as bio-inspired, bionic and bio-assistance. If the idea to observe nature to learn and to develop technologies, and concepts are not new, the concept of biomimicry is quite recent. It was popularized in the 1990's by Janine Benyus in her book *Biomimicry: Innovation inspired by nature* (1997). She interconnects it with the sustainable development.

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excludes:

- Genetically Modified Organism (GMO): “nature-based solutions exclude methods that artificially alter nature, such as GMO” (European Commission 2015).
- Bio-materials (cf. Presentation of Marie Yeroyanni (EC expert) at the N4C General Meeting in Vienna in 2017.)

II.4.3 The NBS definition of the EC rephrased in N4C

Based on the previous analysis, for our research project, we propose a rewriting version of the EC definition based on the existing variants:

A proposal rewriting version of the EU definition (2015) rewriting in N4C:

Nature-based solutions are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives. They recognize the importance to develop a systemic approach and at the same time to adapt interventions to the local context. They also integrate the temporal factor to meet the challenge of durability.

They are actions inspired by, supported by or copied from nature. Such solutions bring more, and more diverse, nature and natural features and processes into cities. They are living solutions, and as much as possible they take part in complex and functional ecosystems. (note that GMO, and other solutions that artificially alter nature are excluded.)

Nature-based solutions use the features and complex system processes of nature. By using the natural flows of matters and energy, these are low-input solutions. If these solutions are conceived and implemented in a good way, low-maintenance, cost savings, energy and resources efficiency are expected. NBS also benefit from the malleability of nature (capacity to evolve and to adapt) and are thus more resilient to changes.

They both use and enhance existing solutions to challenges, as well as explore more novel solutions.

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III. Discussion on NBS applications – what do NBS concretely look like?

The previous part clarified the existing and interpretable theoretical principles and definitions of NBS and thus defined the concept for the N4C project. However, these definitions remain theoretical and need to be illustrated by practical cases of NBS. The EC, by many ways, brings some more concrete elements, but there is still a need for a "translation" between NBS theory and concrete applications. Here are some questionings extracted from our discussions:

- Do NBS necessary refer to interventions which use vegetation?
- How to consider a solution which combines green roof with solar panels for example? Is it a global NBS or should we distinguish two distinct solutions (a NBS and a renewable energy solution)?

A discussion is therefore necessary between the theoretical reflection and the classification of concrete cases of NBS.

III.1 Method of the discussion on NBS applications

Our early discussion on NBS applications started on non-exhaustiveness list of candidate NBS. But, in order to structure the discussion, we then chose to frame it with the main fields of intervention in the city. They have the advantage to be an entry both for scientists and practitioners.

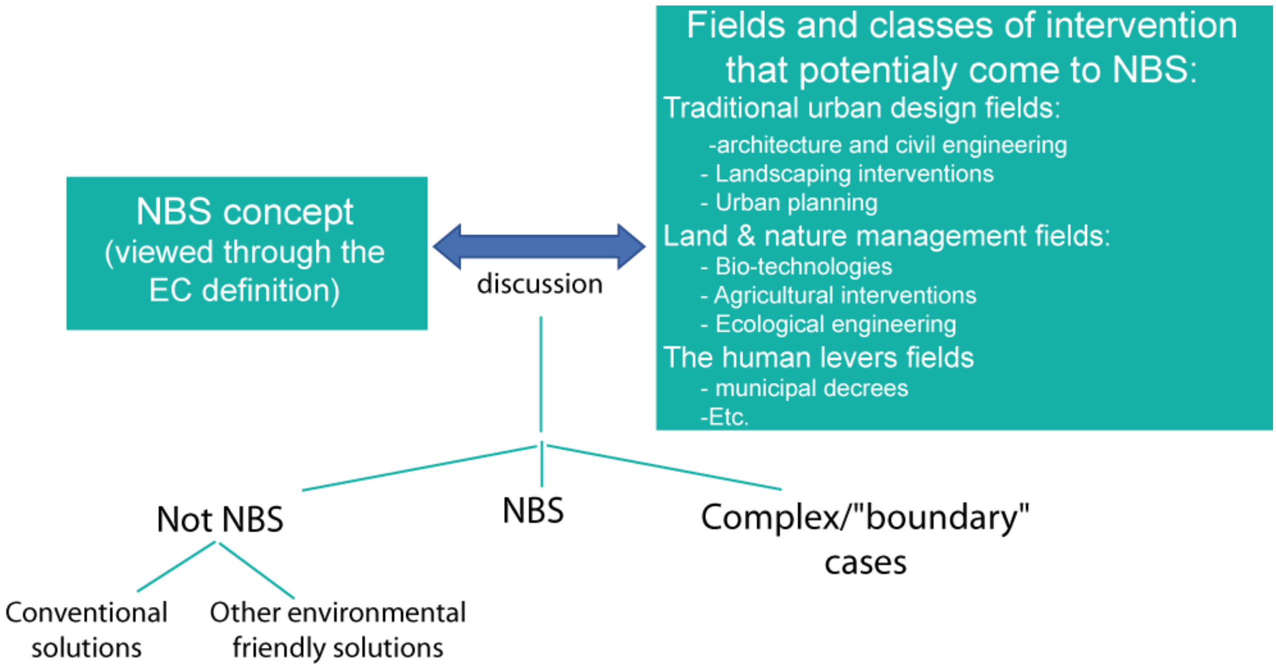

Figure 11: Diagram presenting the method to discuss the concrete applications of NBS

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How do the several fields of interventions in city have been chosen?
From the lot of fields of urban interventions three main fields have been selected for evaluation, because these are in closest contact with NBS. Fields are divided into further classes of intervention:

- Traditional urban design field (Lang 2005): architecture, civil engineering, city planning and landscape architecture.
- Land and nature management field: ecological engineering, agriculture, biotechnologies. These ones are not necessarily linked with the city, but they are more and more involved regarding the current challenge of re-naturing cities.
- The human levers (socio-cultural levers, ways to influence uses & practises) field: the ways of intervention in the city are not limited to design and to the interventions on bio-physical structures. The interventions can target the city-dwellers themselves through the citizen awareness, the citizen engagement, the public rules, etc.

Delimitation and connection between the classes of intervention
Classes of intervention are presented separately for clarity. Although in reality, they are highly connected.
For example, even if landscaping interventions and ecological engineering develop specific applications, they both share a good knowledge of ecological processes. In a similar way, at the interface with architecture and civil engineering, the landscape architecture also develops small buildings and infrastructures.

Organization of the discussion implemented in III.2
Each class of intervention is treated in a separate section. Each section consists of a table. The discussion first reviews and clarifies several aspects of each class of intervention (left column). These ones are then discussed in the right column, regarding two main axes:

- Is there coherence with the main NBS principles?
- Do the interventions match with the EC definition of the NBS that we have selected in N4C?
  (This second axe implies that we (N4C) recognize that solutions not considered as NBS according to our definition, could be considered as NBS from the point of view of other definitions.)

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III.2. Discussion on NBS regarding different classes of intervention on the city

In the selected urban intervention fields there are 7 classes of interventions (specified in the previous subsection) evaluated according to the relevance from NBS definition. Each class has different important aspects that should be differentiated, because they have specific relevance from the point of view of NBS performance and management. The aspects are different in the case of each classes of interventions, because they have quite different characters (architectural intervention, biotechnologies, ecological engineering, etc.), the differentiation of these aspects were based on expert knowledge of the writers.

III.2.1 NBS versus architecture and civil engineering (structures and infrastructures)

Different aspects of this class of intervention	Discussion: are they NBS?
Conventional technical solutions and their today's modernization: - storm water basin - more efficient HVAC - soil sealing such as cool pavement - chemical pesticides -etc.	The NBS concept is partly built in opposition of these hyper-specialized approaches. These solutions are based on physical or chemical principles (run-off, gravity, fluids properties, and protein inhibitor). These principles may be related to "inspired by nature" as principles but without any link with a living principle or property. These are not supported by nature. Many of them need high electrical or petrol energy supply, and/or limit life and nature installation. → they are not considered as NBS because they are hyper-specialized and not living solutions
Traditional solutions: - use of local natural materials (local-stones as construction material) - basic attributes of bioclimatic design - cotton awning - etc.	These solutions can be included in the wide frame of NBS. "That makes sense". Indeed, they refer to elements of nature (wind, sun, geology, etc.). They are low-energy consumption solutions. By consequence, it is possible that some NBS definitions identify them as NBS. It is important to note that some of these solutions are not renewable solutions and can even have a negative impact on nature. It is the case for example for stones mining. However, these solutions have not the "living character" expected in the EC definition. → they are not considered as NBS in the N4C framework. But they could after a deeper assessment join the NBS in the larger category of "Environmental Friendly Solutions."
[New] alternative solutions to conventional approaches. Often inspired by traditional solutions but now developed with modern	Same analysis as previously. In addition, these solutions bring more questions about the level of human intervention. Because even

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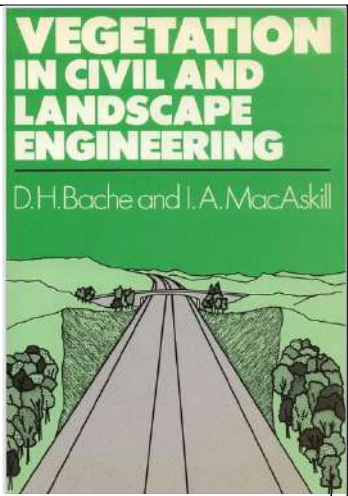
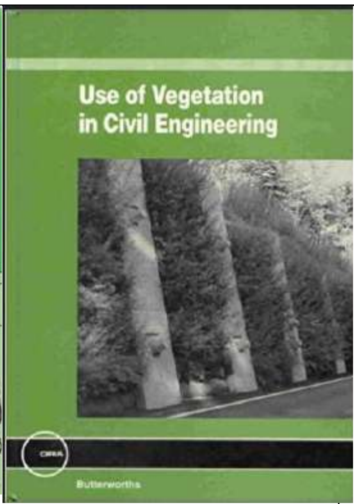
technologies: -bioclimatic design -utilization of renewable energies sources: biogas, wind turbine, solar panel, etc. -re-used materials -bio-sourced materials -technical awning systems	if they are still initially based on natural elements some of them develop high technologies. We will see in the section IV that the level of human intervention can also be considered as factor to analyse the NBS. → they are not considered as NBS in the N4C framework. But they could after a deeper assessment join the NBS in the larger category of "Environmental Friendly Solutions."
Use of vegetation in civil engineering -re-vegetation (generally after levelling works) -more complex applications can be get close to ecological engineering (cf.III.2.5) -vegetation integrated on buildings (walls, roofs) or in pavement (pervious pavements)	Even if they can be grounded on a base build by civil engineering methods, these applications are often implemented in partnership with landscape architects, biologists, ecological engineer, etc. The principle is to use (1) the root network of plants to stabilize the soil and (2) stems/leaves on the surface to cover and protect the soil against erosion (water drop impact, wind) and water runoff (water speed regulation).They also are support of life. → they are considered as NBS

		
David H. Bache, Iain A. MacAskill, 1984, *Vegetation in Civil and Landscape Engineering*, Granada Publishing, 301 pages.	Coppin, N, Richards, I., Barker, D.,Morgan R. and Rickson, J. (1990): *Use of vegetation in Civil Engineering*, Ciria, p 312	http://www.pm10inc.com/erosion-control/erosion-control-hydroseeding/
Figure 12: Some references on the use of vegetation in civil engineering		*Figure 13: Re-vegetation and erosion control using the hydro-seeding system*

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III.2.2 NBS versus human levers

Humans modify physically their environment. A possible class of intervention is to intend to inflect on people's behaviour. It can be divided into direct inflections on uses and practises, or indirect inflections on socio-cultural levers (mental representations of people). It allows to:

- preserve/protect/maintain an ecological state of the environment (providing services)
- restore an ecological state of an area

Different aspects of this class of intervention	Discussion: are they NBS?
Direct inflection on uses and practises in relation with a specific area -restricted access to an area -limit or prevent specific uses and practices in an area	The link with a specific area relates the character of a solution to an identified problem. These actions prevent a NBS performance loss or NBS destruction from direct/physical factors (see Figure 13 for example). → they are NBS
Indirect inflection on uses and practices -awareness (communication campaign, pedagogic panels, etc.) - environmental education - etc.	These interventions take part in a general awareness of the importance to care about our environment. They are an investment for future but, they cannot be directly linked with specific objectives, which remain a hypothetic character (see Figure 14 for example). The distance between these actions and the NBS protection has been considered substantially important. → they are not NBS In a specific context, an awareness campaign for example, can facilitate the acceptance of a NBS project. The awareness campaign is not the solution itself to the problem, but takes part in the implementation. As the financial incentives or rules and regulations, these interventions accompany the NBS. → they are still not NBS

Figure 14: A limit along the Garonne river in Bordeaux to preserve the specific humid habitat of the estuary (Photo: Bodénan, 2013)

Figure 15: A pedagogic panel in Lyon (Photo: Bodénan, 2013)

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III.2.3 NBS versus bio-technologies

The OECD defines the bio-technologies as "*The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*." (OECD, 2005). This definition is broad. We propose to distinguish two perspectives, the modern bio-technologies and the selection and hybridization of species. The second one is more rarely associated with the concept of bio-technologies but it clarifies the possible questionings.

Different aspects of this class of intervention	Discussion: are they NBS?
Modern bio-technologies - Genetically Modified Organism (GMO)	Modern bio-technologies match with the "living" criteria of the EC definition, but they raise an ethic discussion regarding their naturalness. GMO are clearly excluded by the EC (European Commission 2015) by considering they "artificially alter nature". GMOs induce side-effect and impact to nature, as gene pollution, higher use of pesticides, loss of biodiversity. → they are not considered as NBS in the N4C framework.
Selection and hybridization of species traditionally practiced in agronomics and in horticulture -horticultural species	This traditional activity is not concerned by the polemic on modern bio-technologies. Moreover, the horticultural plants are tolerated among natural species because NBS are compatible with technology and human intervention. The side-effect and impacts quoted here-above are not related to this case. In the contrary, this induces a bigger agricultural biodiversity and lower use of pesticides.→ they are considered as NBS

III.2.4 NBS versus landscaping interventions

Landscaping solutions are characterized by the use of natural and biological materials such as vegetation water and soil. It also touches small building works, street furniture's etc. But whatever we consider, they care about the peculiarities of the outdoor environment. This field of intervention is linked with different scales from the object scale (the choice of a plant species), to regional scales (a green network).

The landscape architects have different sensibilities. Some of them give more place to plants whereas other privilege structures and materials (Figure 16).

Considering scale approach and practitioner's sensibility, we propose to distinguish three variants (nota: landscape planning will be develop in the section III.2.7, with "Urban planning") :

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Different aspects of this class of intervention	Discussion: are they NBS?
Landscape architecture highly connected with traditional techniques derived from parks and gardens tradition ⇨ plants as a living material is a privileged tool	These landscaping solutions are the most used examples to describe NBS in urban context. They compose with the existing environmental conditions and use themselves living materials. → they are considered as NBS
Some currents of modern landscape architecture emancipate from park and garden tradition. They are closer to urban architecture by privileging refined street furniture's, hard materials, minimalist spaces using surrounding facades etc. (Lenzholzer 2008)	These landscaping solutions take in account the natural environment to better go out of it. They are not support of life. →They are not NBS
Contemporary landscape architecture that is highly connected with architecture and develops new techniques to install nature in very dense city.	Architectural solutions can imply or emphasize the connection between men and nature, highlighting the complexity yet simplicity of nature. For example by using small-scale NBSs in a typically urban environment (event space, pedestrian street, parking lots, etc.) (See Figure 17– Old elevated trainline in New York was re-natured instead of demolishing. This way a nature-close area was set and demolishing waste was not arised).

Theater square, Rotterdam (Photo: A. Geuze - West 8)

Maximilianpark, Hamm (Germany), (Photo: P. Oudolf)

Figure 16: Two projects of landscape architects with different sensibility toward natural elements

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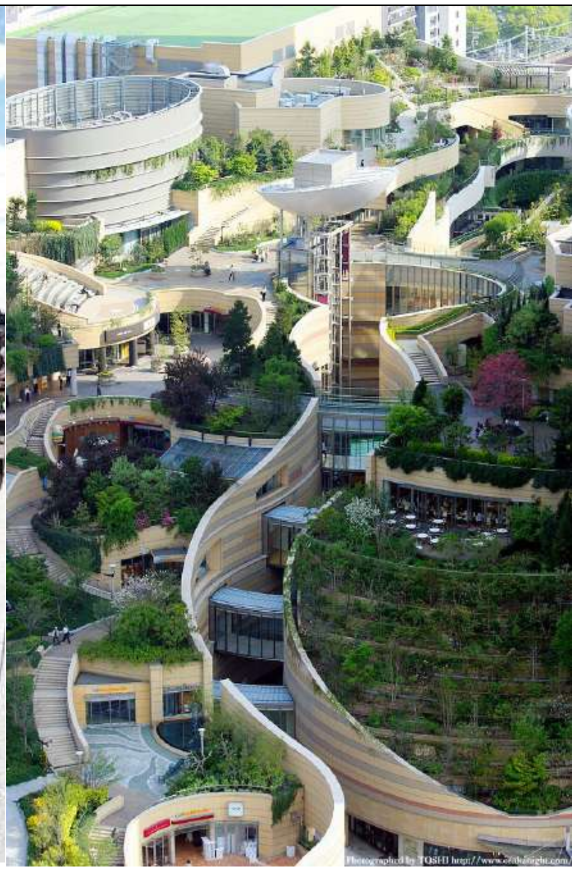
Source:
https://www.worldcitiesnetwork.org/knowledge-hub/article/engineering-the-living-city-101/

Figure 17: *The High Line (2.33 km elevated linear park, greenway and rail trail,, New York, USA*



Source:
https://rumahijau1.wordpress.com/2013/03/04/landscape-architecture-urban-design-in-namba-parks-osaka-japan/

Figure 18: *Eight level rooftop garden in Osaka, Japan*

III.2.5 NBS versus agricultural interventions

This field of interventions concerns old and new practises of agricultural production in city. Urban agriculture is a traditional practise in peri-urban areas, but it also sometimes takes place at the earth of the city (for example allotments). The main goal of these interventions is the production of resources (in particular food) for the need of city provisioning.
But a lot of them integrate many other purposes such as biodiversity, environmental education, and recreational activities.
These activities are generally adapted to small surfaces and mainly intensive management: horticulture, small farming, roof gardening, etc.

Doing agriculture in the city is a quite trendy and fancy activity. More and more community gardens were opened in recent years and young restaurant owners are growing and harvesting their own vegetables from the garden on the top of the restaurant. (e.g. Massimo Bottura's restaurant chain, Figure 19).

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Figure 19: The Bachelor Farmer Restaurant in Minneapolis, USA

Different aspects of this class of intervention	Discussion: are they NBS?
Agriculture based on (revisited) traditional techniques -honeybee -grazing animals -urban farms -market gardening -community garden - balcony gardening	These solutions have two origins. They can be based on relict of agriculture encompassed in the city. But they also can be re-introduction of agriculture These solutions are an innovative way utilizing unexploited areas in the city. Their integration into the urban fabric are developed at different levels. Some remains as enclave in the city, mainly in the peripheral areas like grazing animals or traditional urban farms, while others are fully integrated or reinvent new approach of utilization, community gardening, rooftop gardens. Honeybee keeping in urban areas is not a modern solution but nowadays it has become essential from the aspect of horticulture or urban orchards. → they are considered as NBS
Modern (high-technologic) agriculture -hydroponics -aquaponics (Figure 20) -storeyed greenhouse -microalgae façade	In some cases, these techniques only help to face the city constrains (pollution of soils, lack of deep soil, lack of place, etc.). High-tech, or rather soft-tech agricultural technologies can accelerate the possibilities of producing food in densely built-up urban areas (Figure 21). Nevertheless, they keep integrated in the rest of the urban environment. However, in some cases, the productions are completely based on hydroponics systems. → Are they NBS? It depends from the context in which they are mobilized.

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 Source: https://www.designboom.com/architecture/ilimelgo-architects-vertical-farm-grand-paris-03-22-2016/	 Source: https://www.designboom.com/architecture/ilimelgo-architects-vertical-farm-grand-paris-03-22-2016/
Figure 20: Mixture of aquaponics and hydroponics in Debrecen, Hungary	*Figure 21: Vertical farm design by ilimelgo architectural firm 2016*

III.2.6 NBS versus ecological engineering

Ecological engineering is based on an in-depth knowledge of ecosystems and especially the animal behaviour, the physical properties of plant roots, etc.
Ecological engineering definition is ambivalent, these interventions are both defined as a mean or/and as a finality (Rey & al., 2014). In the first case, it refers to the interventions using plants and ecosystems features to solve human challenges. In the second case, this refers to the interventions centred on and ensuring the benefit of non-human species. We distinguish these two aspects in the table below:

Different aspects of this class of intervention	Discussion: are they NBS?
Interventions based on the knowledge of plants and ecosystems and physically mobilising them -ecological restoration (to get benefits from ES) (Figure 23) -phytoremediation -constructed wetland -use of plants to reduce erosion -swale, rain garden	These interventions fully encompass the NBS criteria. They are one of the NBS archetypes. → they are considered as NBS
Interventions that target to reduce impact on fauna and based on civil engineering structures and infrastructures -wild animal passage (Figure 22) -bats house and nesting box	These kinds of interventions target ecological challenges but they tend to be highly specific to only one objective. They ensure the continuity of ecological network when they are cross over by roads or railways. Furthermore, they can be costly solutions. → they are not considered as NBS However, these solutions can be complementary with NBS, for example for ensuring punctually the continuity of the green network. So they take part in the large spectra of the environmental friendly solutions.

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  Photos: Cerema	  Photos: Chateauvieux M. & Guillet M.-P.
Figure 22: Wild *animal passages based on heavy civil engineering structures – Not NBS*	*Figure 23*: *Hermanence river restoration (Veigy-Foncenex, France) mainly using vegetation - NBS*

III.2.7 NBS versus urban planning

Urban planning is a complex process, where several professions are concerned, and an integrated approach is needed.
Spatial planning is everywhere in national scope, thus the planning systems of European countries differ from each other. From the point of view of implementing NBSs we can differentiate two different types of plans:

- Land use plans >
- Development plans >

Furthermore, we can state, that urban planning is a process composed of different stages. There are usually three main stages need to be distinguished:
1. Assessment of the current situation: the first stage of planning is about getting to know the state-of-art, collecting data, previous studies that are necessary to evaluate the planning area. This also contains the knowledge of future urban long- and medium-term development concepts and strategies. Engagement of the stakeholders is essential part of planning from the first stage. During this stage of planning usually planners gather the needs and demands of stakeholders.

2. Planning: the second stage is planning itself. Based on the collected data and information, and involving the necessary sectoral planners, the targeted urban plan is created. During the planning stage participatory planning ensures that the ideas of stakeholders is

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incorporated into the plan.

3. Finalization: during the third stage of planning the created plan is consulted with the customer authority and after incorporating the needed changes, the plan is approved.

Urban planning usually concerns 3 main scales: regional, city-scale (or district) and neighbourhood and object scale. By implementing NBS we focus on the latter two scales, identifying land use and development plans as also mentioned before.

Different aspects of this class of intervention	Discussion: are they NBS?
Knowledge and diagnosis stage: ● gathering data and information on current stage, including the systematic review of existing plans and strategies ● set-up of proceedings and urbanism rules– - definition of potential developments ● Traditional, continental land use plans: dealing with land use, and with zoning regulation based on continental land use plans. It gives a framework to the different actions by ensuring the long-term infrastructural needs.	Obviously, these categories of plans cannot be considered as NBS themselves. But there are possibilities (almost in every types) to use an approach, include a specific workstep, etc., because of which they can be distinguished as NBSs, e.g.: - conceptual framework for using NBS (in knowledge and diagnosis stage - defining the ratio of built-up and vegetated areas (in general or concrete project-oriented development plans) - preserved nature, buffer zones (in development plans) → they are not considered as NBS
Development plans: aimed at the targeted interventions through fulfilling the needs in a feasible way and determining the possibilities of realisation: ● land use, urban structure plan ● sectoral strategy: (Stadtentwicklungsplan, Landesentwicklungsplan, Local Agenda 21, SUMP, etc. ● Plans for urban regeneration or green fields ● Local Regulation Order	Interventions or theoretical approaches in urban planning can be considered as NBS if they meet these conditions: - use of vegetation as a limit or to structure the urbanization -allow or not to build a plot/an allotment regarding the value of the agronomic soil, and ecological continuity, etc. - Conservation measures: preserved areas included in the city In parallel with the aspects in the previous section, every types of plans can have NBS-oriented parts or approaches that can be considered as NBS themselves. → they are considered as NBS

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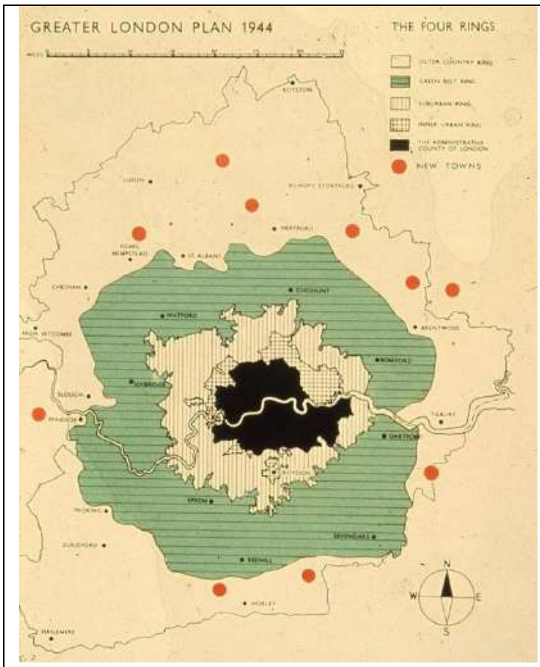	 (Plan: Castro-Denissof, 2005)
Figure 24: *An historical example, The Green belt in London (or Abercrombie's plan) (London, 1944)*	*Figure 25: "Green fingers" - master plan of the eco-district Plateau des Capucins (Angers, France)*

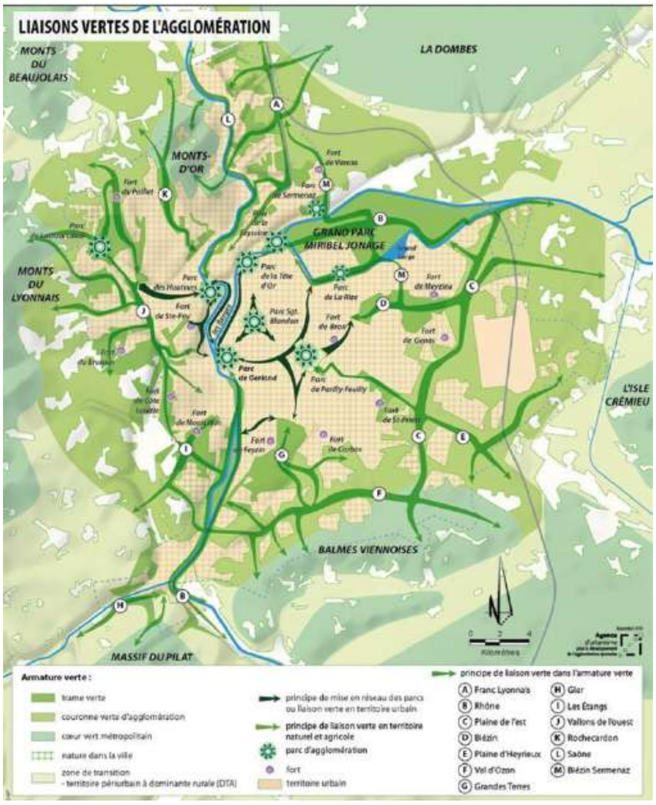

Figure 26: The green network (Lyon)

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III.3 Complex cases: the combined solutions

According to our opinion it is difficult to classify combined solutions (a joint usage of a NBS with another kind of solution). This section proposes to list the mentioned complex NBS cases and to discuss their status in the NBS database.

III.3.1 The types of combined solutions

- The combination of NBS and other environmental friendly solutions

There are several examples for joint utilization:

- Green roof & solar panels
- Green wall & solar panels
- Vegetated pergola & solar panels
- Vegetation and misting & fan systems
- Etc.

 The combination of a green roof and solar panels Photo: Green roofers	 The combination of a green wall and solar panels Photo: Boutique hotel Stadthalle (Vienna)
 The combination of a vegetalized pergola and solar panels Photo: Green4Cities	 *The combination of vegetation and misting and fan systems for a high outdoor comfort – EXPO Pavillion breathe. Austria* Photo: Green4Cities

Figure 27: Examples for combined solutions

- The combination of NBS and conventional solutions

For example, a water management system based on a conventional stormwater harvesting system which comprises a vegetated storm water basin.

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Photo: http://www.taylorengineeringllc.com/stormwater.html

Figure 28: A vegetated water storm basin: a combination of a NBS and a conventional solution

III.3.2 Status of combined solutions

Combined solutions have clearly a place in the NBS database[4]. The question is more about the way to present these specific cases.

There are two possibilities:

1. To present them as a global NBS
2. To distinguish the components of the solutions (NBS, conventional solution, environmentally friendly solution).

In N4C, we decided to use the latter distinction for these solutions. Consequently, the NBS character of the combined solutions will be discussed and assessed, and in other hand, the contribution (positive and negative aspects) of the combined usage will be evaluated too.

Two main arguments justify this approach:

1. An individual characterization the combined solutions as an NBS might be confusing and would make the clear understanding of NBS database difficult.
   For example, the vegetated storm water basin (see above) has many advantages in comparison with a concrete basin (biodiversity, aesthetic, etc.). But this solution cannot be merged with an NBS. At least regarding the challenge of rainwater management it tackles the form and not the content. The principle of the process remains to collect rainwater, what is a conventional solution. A real NBS on the other hand for addressing this challenge would be in favour of implementing green roofs, swales or rainwater gardens that have the potential to store water by infiltration or to slow the runoff.
2. In N4C, we would not assess combined solutions as a whole because we don't develop assessment tool for the environmental friendly or conventional solutions. For example, we do not assess renewable energy system.

[4] In the NBS analysis grid, a special section is dedicated to possible combination of the NBS with other solutions.

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IV. Analysis framework of the NBS

This section explains all the variables used to describe and analyse the NBS. It aims to allow discriminating different NBS, by showing differences and similarities. As a primary stage, the analysis framework participates to the construction of the NBS typology. Indeed, based on significant similarities and differences, NBS clusters will be built. They will then provide a general structure to the types identified in the section III.

IV.1 Selection of relevant variables to analyse NBS

The analysis framework contains different characters which help defining the NBSs.
In N4C, we target to propose an analysis framework that can be accessible to different kind of actors (scientist of different disciplines, practitioners, etc.), and that allow to quickly discriminate different NBS. For that reasons, we chose to limit the number of variables to the key ones. Thus we only retain 5 variables:

- Level of human intervention

It has a specific status as a variable to describe NBS. It is a more complex factor that combines several factors. It especially well summarizes the "spirit" of the principles of the NBS concept. However, because of its complexity it is more difficult to implement in analysis grid, and we propose to keep it as a discussion support.

- Urban challenges addressed

They refer to the challenges addressed by NBS as main challenges and co-benefices. We add a notion of richness that is related to the number of challenges simultaneously targeted

- Urban spatial scales

They are related to the scale(s) at which the NBS is applied and to the scale at which it the NBS has an impact on urban challenges.

- Temporal scales

They are related to the time needed before the NBS is fully effective and to its services life.

- Land cover/environment of the implementation

They refer to the physical environment of the NBS, in other words, the surfaces of implementation or nature of NBS, ground, water, building. It is a particularly operational factor to structure the NBS, because it is linked with concrete sectors of interventions and know-hows.

These families of variables will be described in the following.

IV.2 Notion of level of human interventions

The notion of level of human intervention[5] is one of the earlier and the most intuitive factor to analyze the NBS concept.
Indeed, the concept of '*nature-based solutions'* underlines that the theoretical purpose is about the links between people and nature. The advantage of the concept is to avoid extreme positions (total protection and at the opposite a development without control). The

[5] This variable is directly influenced by the 3 NBS-types classification proposed by (Eggermont et al. 2015). This is (one of) the first classification directly linked with the NBS. However, it does not focus on the urban context.

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idea is -at the same time to meet the anthropic challenges and, to limit the impacts on the environment (Maes and Jacobs 2015).
It meets the compromise positions that are expressed in “Sober city” or “to do as much as possible for and as little as possible against” (Clément, 1991).
The concept allows a wide range of solutions based on industry and high technologies: GMO, bio-mimicry (including highly technology), industry based on wind/solar/bio-materials, etc. to the simplest ones: preserved natural areas, etc. These configurations can be placed on a gradient from low to high level of human interventions (Figure 29, Figure 30). This approach can help the evaluation process (mainly in NBS performance assessment and socio-economic impact assessment phases).

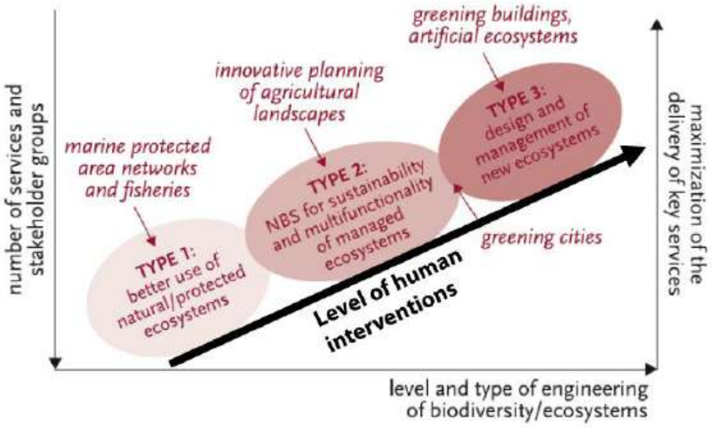

Figure 29: 3 types of NBS placed on a gradient (Eggermont et al. 2015 modified 2018)

According to Eggermont et al. (2015, 2018) (Figure 29) shows the schematic representation of the range of nature-based solutions approaches. Three main types of NBS are defined, differing in the level of engineering or management applied to biodiversity and ecosystems (x-axis), and in the number of services to be delivered, the number of stakeholder groups targeted, and the likely level of maximization of the delivery of targeted services (y-axis). Some examples of NBS are located in this schematic representation.

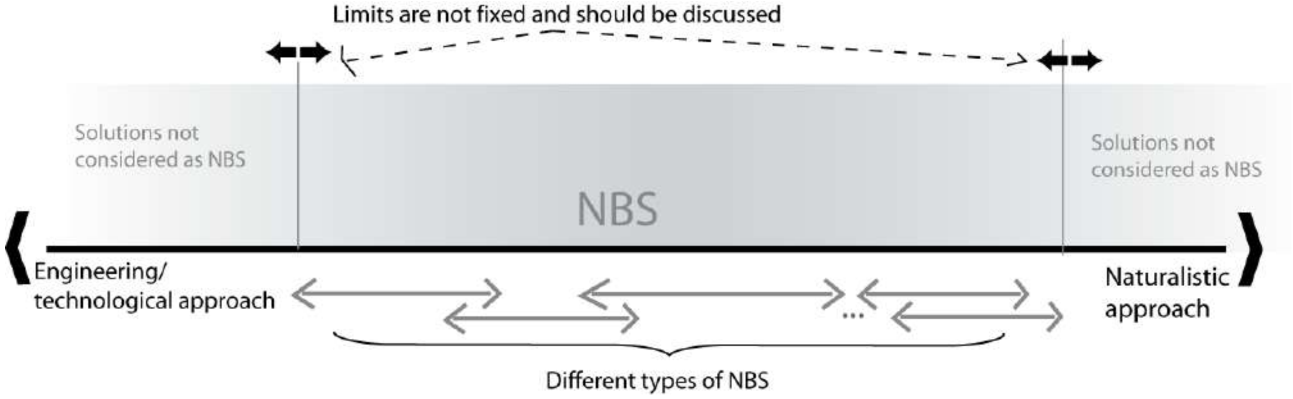

Figure 30: NBS on a gradient of levels of human intervention (Bodénan, 2017)

The factor of the level of human intervention is interesting by opening a debate in which

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everyone can contribute (even without prerequisite). What is more natural? Shade elements that are completely man-made but that require few materials and energy, or a garden made with living plants but requires a lot of energy for management and its initial construction? In another terms, how to place them on the gradient of human intervention to demonstrate them in a hierarchical relationship?

This concept needs to be confronted with concrete examples. It is not shaped to build a theoretical reflection. The risk would be to enter into an endless debate about what is natural or not.

In N4C, this gradient was extended by introducing a scale gradient and developing types by positioning several examples (Figure 31). This can be useful, as a summarizing figure for next phases (relevance of NBSs on different scales is emerging in several parts of the work). The interpretation of the colours in the figure (names of solutions and the ellipses) is the following:

• Black ellipses indicate (mainly) artificial structures, and the usage of artificial materials.

The most left part is for such technocratic solutions that require a great amount of plus energy input like HVAC or motorized shade structures (Especially if they use non-renewable capital, but we do not exclude from this part the engineering solutions that use renewable energy, because the production of these technocratic solutions as well as the end of their life cycle may cause environmental burden as well).

• Green ellipses stand for vegetation-related solutions

• Blue ellipses indicate water-related solutions.

The vertical sizes of the ellipses reflect the number spatial scales on which the NBSs potentially have considerable effects.

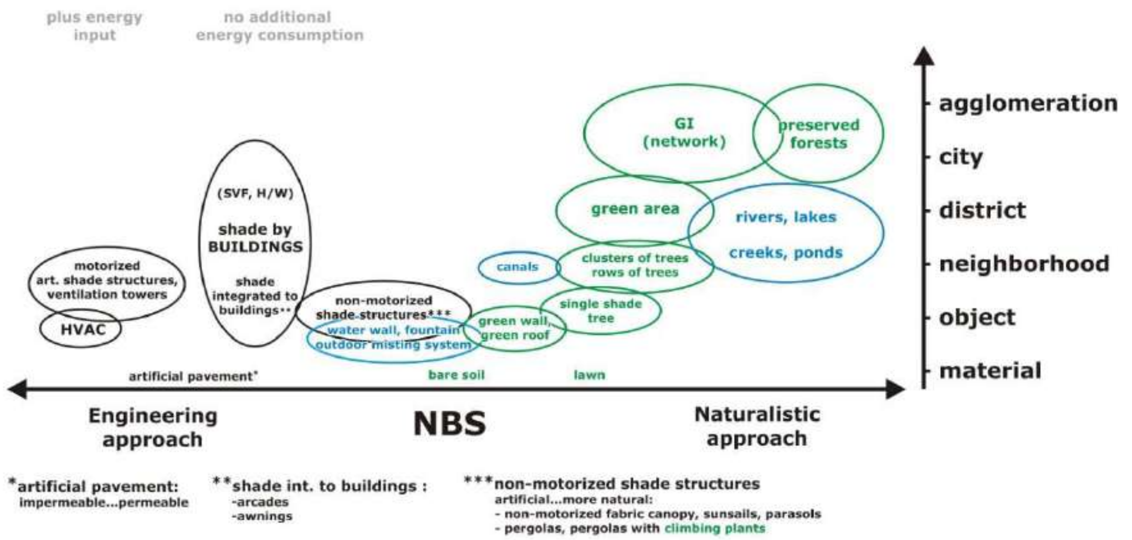

Figure 31: Diagram structuring NBS on two axes: level of human intervention & spatial scale (own figure)

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IV.3 The NBS urban challenges framework

In “NBS”, the term “solutions” refers to specific and contextualized problems. This terminology ("problems", "solutions") is linked with the operational character of the NBS. In order to frame the problems addressed more largely, we focus on the related challenges. By doing this, we focus on the urban context, which is our framework in N4C.

IV.3.1 Identification of urban challenges and frameworks – a review of literature

Based on the ongoing PhD thesis from Babi Almenar (2020) and linked with WP 1 and WP 2, a comprehensive literature review has been performed. This work is presented in the Deliverable 2.1.
Here, we propose to take more distance from the challenges and sub-challenges by considering the large frameworks in which they are included. It helps to understand the main influences that shaped the NBS urban framework.

The NBS urban challenges framework is based on several challenges frameworks:

- The NBS challenge framework

There is an increasing global focus on “re-naturing” urban areas by developing urban green spaces such as parks and forests in post-industrial cities in response to the challenges of attaining urban resilience and environmental sustainability (Gulsrud et al., 2018; Lawrence et al., 2013). Some references such as the EKLIPSE report (Raymond et al. 2017) and the IUCN (Cohen-Shacham et al. 2016) already focused on societal challenges targeted by NBS or climate resilience (Kabisch et al., 2016). However, these ones are for the moment rarely specific to the urban context. They more often concern the rural and natural areas (Keesstra et al., 2018). Nature-based solutions are all concepts based on an ecosystem services approach, but they use adapted terminologies to mainstream biodiversity and ecosystem values in specific sectors (Maes and Jacobs, 2015).

- The challenges related to the sustainable urban development framework

The sustainable urban development is a concept explored in the 2000’s. Several frameworks have been developed on it, at the city and district scales or at the building scale (Figure 29) (Appendix 2: Urban challenges).
The literature on sustainable urban development is complementary to that specific to NBS. It allows to address challenges such as waste management, energy production, safety, etc. which are not addressed by the NBS frameworks (IUCN, EKLIPSE or N4C). Pursuing all of these targets has long been seen as impossible. However, any all of these challenges depends on the extent to which natural resources are used sustainably.

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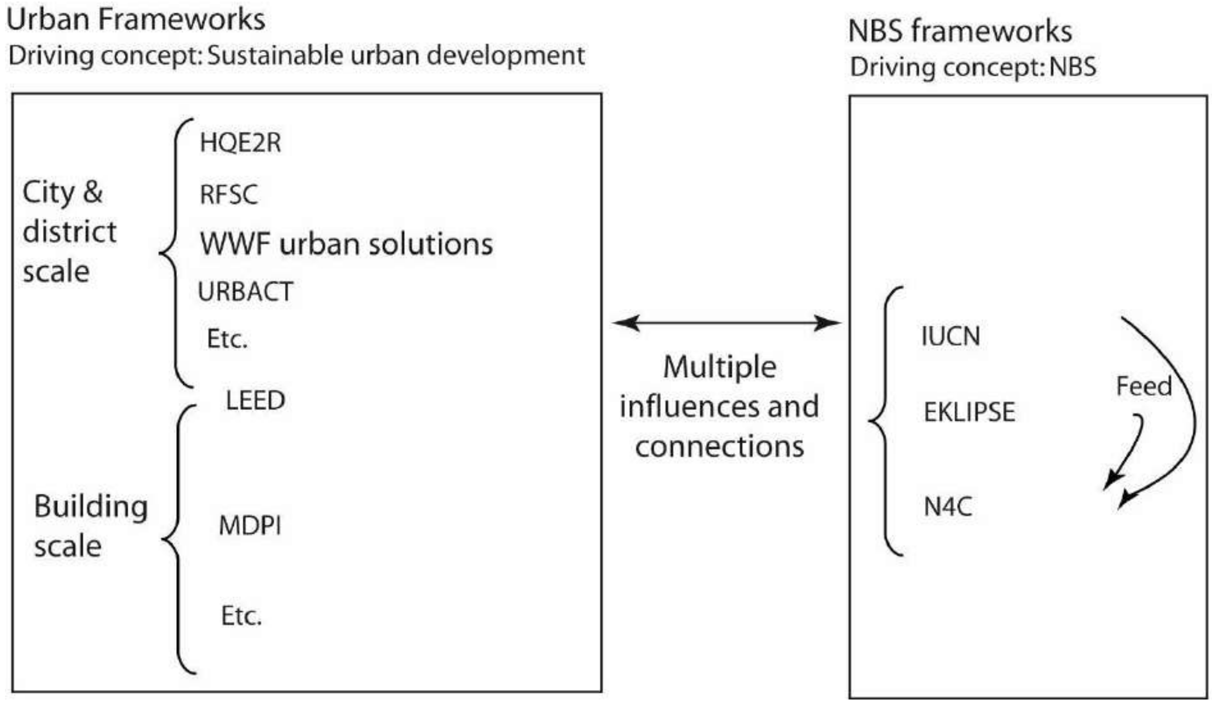

Figure 32: Connection between the Urban frameworks and the NBS frameworks

IV.3.2 Urban challenges selected in N4C

The selected urban challengers are based on the reflection of WP2 group. The methodological approach involved a literature review combined with expertize within the WP2 group. They primarily selected five different main topics: climate, environment, resource, social and economy. The selection of the urban sub-challenges (Figure 33) was inspired on five steps methodology:

- Set-up of expert groups
- Deep literature reviews
- Documentation of indicators' factsheets
- Evaluation of urban performance indicator (UPI) through RACER criteria (Lutter and Giljum, 2008)
- Weighted scoring on RACER sub-criterions as an attempt to select key performance indicators (KPIs)

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TOPICS	URBAN CHALLENGES (UC)	URBAN SUB-CHALLENGES (USC)
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation
		1.2 | Climate adaption
	2 | Water Management	2.1 | Urban water management and quality
		2.2 | Flood management
ENVIRONMENT	3 | Air Quality	3.1 | Air quality at district/city scale
		3.2 | Air quality locally
	4 | Biodiversity and urban space	4.1 | Biodiversity
		4.2 | Urban space development and regeneration
	5 | Soil management	5.1 | Soil management and quality
RESOURCE	6 | Resource Efficiency	6.1 | Food, energy and water
		6.2 | Raw Material
		6.3 | Waste
		6.4 | Recycling
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics
		7.2 | Quality of Life
		7.3 | Health
	8 | Environmental Justice and Social Cohesion	8.1 | Environmental justice
		8.2 | Social cohesion
	9 | Urban Planning and Governance	9.1 | Urban planning and form
		9.2 | Governance in planning
	10 | People Security	10.1 | Control of crime
		10.2 | Control of extraordinary events
ECONOMY	11 | Green Economy	11.1 | Circular economy
		11.2 | Bioeconomy activities
		11.3 | Direct economic value of NBS

Figure 33: Nature4Cities' list of Urban challenges (UC) and sub-challenges (USC) out of T 2.1

IV.3.3 Key notions to analyse the relation between urban challenges & NBS

By definition, the NBS refer to a systemic vision. NBS are supposed to target several challenges (at the opposite of hyper-specialized solutions). Three notions complete the property:

- the notion of richness

NBS are not equal. They respond to packages of challenges of different sizes. For example, one NBS is linked with 2/3 sub-challenges whereas another is linked with a ten of them. That is why we proposed to introduce the notion of richness to describe the capacity of a NBS to respond to several UC.

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- the notion of hierarchy

NBS can face several challenges at the same time, but there often remains a main challenge targeted, and co-benefits at a 2[d] or at a 3[rd,] etc. levels. In an extreme case, co-benefits can be considered at the margins. Therefore, it is necessary to take into account a hierarchy of the urban challenges.

- the notion of trade-off

The relations between the challenges are complex. Linked with the notion of hierarchy, it is possible to find NBS that target simultaneously several challenges with a high effectiveness. However, challenges are often contradictory, and to target more efficiently a challenge can imply to be less demanding on another challenge. Thus, it is possible that the implementation of some NBS can have a negative impact regarding non-targeted challenges.

There is a need of trade-off. But this does not question the global “positive response” of the NBS to societal challenges, if this trade-off is anticipated and integrated in the decision (political) process.

IV.4 Urban spatial scales

IV.4.1 A review of literature on urban spatial scales

In an interdisciplinary perspective, we consider several classifications in the scientific literature (Oke 2006; McGrath 2005; Castrignanò et al. 2000, etc.). Each one is shaped for a specific studied object. For example, different scales can be identified as following: political criteria (administrative areas), morphology criteria (density, type of land cover, layout of buildings, etc.), functioning criteria (centre, fringe, etc.), etc.

In N4C, we examined several schemes (theoretical and operational ones):

- **Urban climate scales**

As the effect of urban environment on climate is scale dependent, urban climatology defined adapted urban scales (Figure 34). These scales refer to specific climate studies (Oke 2006). For example, human comfort will not be studied at a large scale as it implies studying the exchanges between a human body and its direct environment.

- Mesoscale refers to scales of several hundreds of square kilometers (to be compared to a city size).
- Local scale is applied to sites spread on several dozens of square kilometers (to be compared to districts)
- Microscale refers to several thousands of square meters sometimes less (to be compared to the urban block, street, place, building…)

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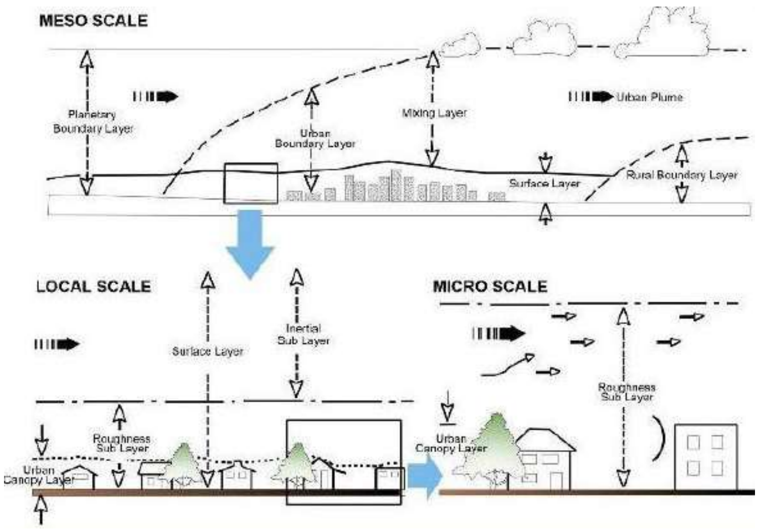

Figure 34: Urban scales applied to climate (Oke 2006)

- **Urban planning intervention scales**

Urban planning generally refers to part of the city corresponding to different urban scales: agglomeration, city, district, neighbourhood and object. McGrath (McGrath, 2005) founded that fundamental economic factors are of primary importance in determining urban spatial sizes. Changes in population, income, transportation costs, and agricultural land values determine nearly 90% of the variation of urbanized land areas. This way of describing the scale correspond to the urban planning tools on which urban planners (or architect, landscape planners) use in their everyday work.

- **Urban soil scales**

Soil properties are mainly influenced by natural factor and anthropogenic activities acting at different spatial and temporal scales. Some of the affecting factors that controlled the soil variability may have a short-range action, whereas others are likely to operate at longer distances. Consequently, the soil properties are expected to be correlated in a scale-dependent way (Castrignanò et al. 2000). The main feature of urban soils is the high spatial (centimeter-to-decametric) spatial heterogeneity of their physical, chemical, and biological properties (Béchet et al., 2009; Blanchart et al., 2017). This variability is explained by the fact that they provide a wide variety of uses: support for buildings (for example, residential, commercial and industrial), infrastructure (for example, roads and railways), recreational facilities (for example, sports, recreation, etc.) or the production of biomass (for example, vegetable gardens or parks) in a restricted area: the city. These numerous uses, frequently superimposed over time, result in profound changes in the initial state of the soil by mixing, incorporation and export of earthy and technical materials, by settlement and by partial or total sealing (Baumgartl, 1998). This heterogeneity implies a much greater variety of urban soils than in other environments. Zhao et al. (Zhao et al., 2010) defined in their study the urban scale to explore the correlations among soil heavy metals (Cu, Zn, Pb, Cr, Ni, Cd, and Hg) across different spatial scales, identify the sources of spatial variability, and evaluate the potential risk of soil contamination. They used two different scales: (i) short-range scale (radius: 2 km) and (ii) long-range scale (radius: 11 km). In addition, McClintock (McClintock, 2012) evaluated the existing and potential urban garden sites in the U.S. (Oakland and California), identifying potential contamination at selected sites. The author used three scales: (i) site-scale sampling with a spatial resolution lower than 100 m, (ii) neighbourhood-scale (radius: 1 km) and (iii) city-scale with spatial resolution lower than (2.5 km). In all cases, the different sampling campaigns were made on the topsoil (0 – 20 cm).

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- **Urban ecological scales**

The issue of scaling impinges on every aspect of landscape ecology and much of ecology in general. Ecologists defined scale in terms of grain (or resolution)—the finest distinctions made in a data set (or model), and extent—the scope of the study in area or time. In lazy shorthand, small (or fine) scale will refer to fine grain and small extent, while large extent (Urban Dean L., 2005). Scale in a critical consideration in all landscape ecological studies for several reasons:

  - Local biological interactions can decouple systems from direct physical determination of patterns (Krummel et al., 1987)
  - Ecosystems do not exist in isolation; they are typically "open" with respect to the movement of energy, materials, and organisms into and out of the system (McGarigal et al., 2002)
  - Different patterns emerge at different scales of investigation of virtually any aspect of any ecological system (Fuhlendorf and Smeins, 1996)

The pattern: process dynamic is arguably the fundamental axiom of landscape ecology because the spatial composition and configuration of landscape elements directly determines how landscapes function, particularly in terms of species movement, nutrient and water flows (Turner, 1989). Because landscape pattern and process are highly interrelated and interdependent, both must be understood to plan for sustainability (Ahern, 2007). In the ecological processes and landscape ecology, the spatial scale is defined as spatial configuration and this concept is built on three fundamental landscape elements: (i) patches, (ii) corridors, and the (iii) matrix :

Urban Patches	Urban Corridors	Urban Matrix
• Parks • Sportsfields • Wetlands • Community Gardens • Cemeteries • Campuses • Vacant Lots	• Rivers • Canals • Drainageways • Riverways • Roads • Pathways for walking • Powerlines	• Residential Neighbourhoods • Industrial districts • Waste Disposal areas • Commercial areas • Mixed Use Districts

Figure 35 : Examples of Urban Landscape Elements Classified in the Patch-Corridor-Matrix Model (Ahern, 2007)

IV.4.2 Urban spatial scales selected in N4C

In N4C, we privilege a common and simplified structure of scales. In order to find a grid that can be shared by different disciplines, we focus on “action scales”, which are currently used by town-makers and managers. This enables to prepare the future assessment developments (WP6) on the N4C platform (Nature4cities tools and platform development). This platform will be based on the well-known Service Oriented Architecture (SOA).

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Finally, we have selected three main urban scales:

1. **The city scale**: It refers to an agglomeration, which is a large, densely and contiguously populated area consisting of a city and its suburbs. It can also refer to a city, which is usually based on a country basis (from a few kilometres to several kilometres)
2. **The neighbourhood scale**: It is an area or section of a city defined either by administrative division or by a distinguishing character. It corresponds to the more or less extended neighbourhood of buildings. It refers to a particular region, district or a part of the neighbourhood level which means a larger subset of a city or a space with specific characteristics (from a few hundred metres to several kilometres)

3. **The object scale**: It refers to building/renovation mostly on open space level with local characteristics (from a few meters to several hundred metres) (Barbano et al., 2015). The real scale will depend of the considered object, it can be a small scale as a window to higher, from roof, building and tree to parking lot.
   The object is the elementary scale of NBS. We do not consider independently the technologies and know-hows linked to the NBS as NBS themselves. Indeed, even if they are strongly linked with NBS, they are not contextualized in a specific place with specific challenges. It has no sense regarding the complexity[6] of the concept.

IV.4.3 Relation between urban spatial scales & NBS

The spatial scales are fundamental to analyse the NBS. Three axes can be identified:

- The urban spatial scales at which NBS are implemented

The scale of implementation is probably the easier to grasp. It refers to the physical aspects of the NBS. It is the scale at which the project has been implemented. It is often mapped on design plans.

- The urban spatial scales at which NBS impact can be measured

The scale of impact is much more difficult to delimit. The environmental physical and socio-economic impacts of an NBS need to be measured at several scales and furthermore, the exact boundaries are rarely clear. To define the scales of impact is nevertheless crucial for the assessment of the NBS as we will see in the WPs assessment tools developing.

- The inter connections between the scales of the NBS

NBS implemented at large scales (at the city or the district level) can be themselves composed of other smaller NBS. For example, an urban park comprises isolated trees, hedges, lawns, etc. which can be themselves identified as specific NBS at the object scale. That's why NBS can be qualified of "composed" or "simple", if they are linked or not with (an)other NBS.

[6] By "complexity", we understand the property to do links between different challenges, scales, stakeholders, etc.

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IV.5 Temporal scales

We note the importance of the time component in NBS concepts to get fully functional. It is linked with three main aspects:

- Biologic time
  Biological time is basically a temporal factor for time of various biological processes, including the growth time for plants. The plant growth impacts the necessary time for an implemented infrastructure to be fully effective.
  The Biological time also refers to the effectiveness of ecological network practised by flora and fauna (animals) after construction.
  A further component in temporal scales is the seasonal time. Differentiation between deciduous plants and evergreens. Low metabolism activity of plants during winter (importance for constructed wetlands used for wastewater treatment for example).
- Life time cycle
  The second temporal scale is the Life time cycle which elucidates sustainability and effectiveness of different NBS concepts (so that to compare materials or energy needs at different stages). Therefore, the needed time of the construction is considered versus life time and its management, deconstruction, etc.
- Cyclic time
  Cyclic time refers to daily and seasonal variations (day and night, 4 seasons). It is partly linked with the biologic time, but this factor is also useful to describe the climate or energy issues (evolution of the urban heat island, variation of the use of energy depending on seasons, etc.)

IV.6 Landcover – ground/ water/ building

For the NBS description, we considered that an efficient way to group NBS was to identify their physical support, this means if they are built (set, developed)

- on (in, with) water,
- on (in, with) ground,
- on (within) buildings.

This first entry of description offers to non-specialist a very simple way to enter in the classification and leads to very logical large groups of NBS.

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V. The NBS classification

V.1 Method of setting up NBS classification

N4C used a classification methodology based on methods developed in social sciences (Kluge 2000; Elman 2009).

V.1.1 Description of the four stages of the classification methodology

The classification should be seen both as an overview and a continuation stage of the work pursued till now in the deliverable. The first stages (1 & 2) of the classification methodology encompass the definition work, the identification of the variables (identification of the NBS concrete cases) and the development of the analysis framework previously done. The two last stages of the methodology (stages 3 & 4) concern the analysis of meaningful relations and the types construction and characterization which are the emblematic stages of the typology.

Despite, we are now interesting in the two last stages of the classification methodology, it is important to connect it with the previous stages which have a deep correspondence with the main developments of this deliverable.

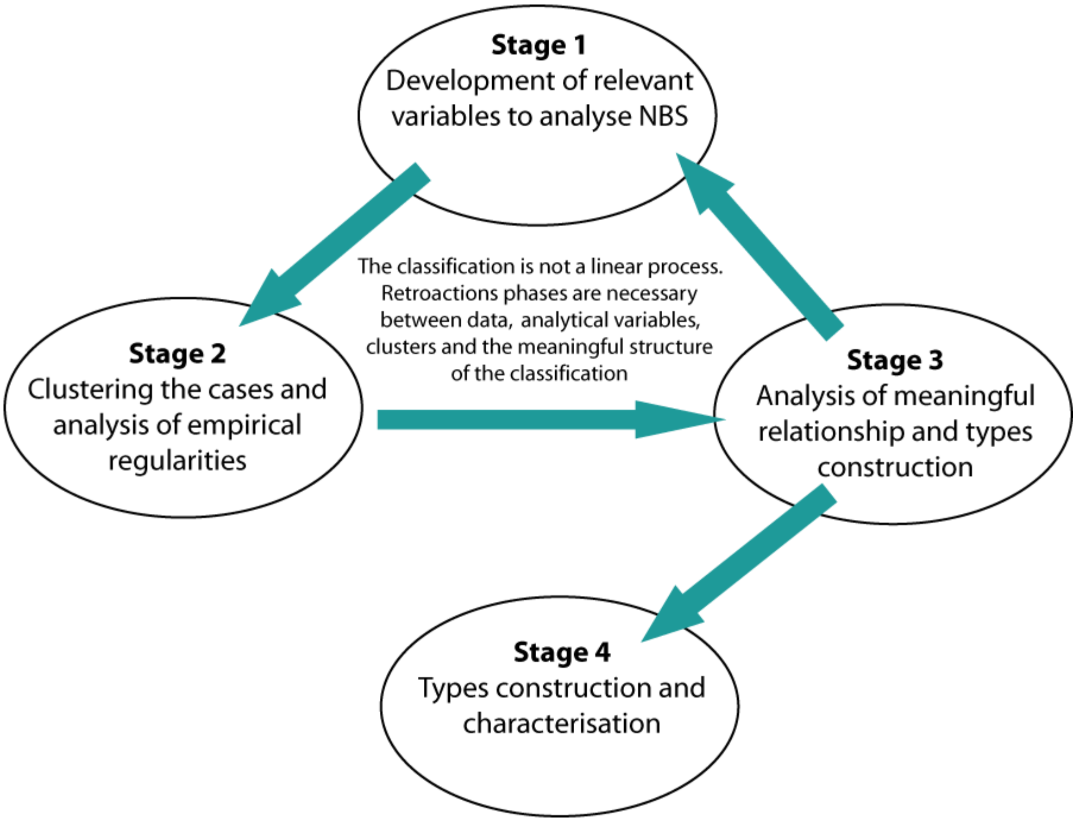

Figure 36: Diagram of the method for the construction of the classification ((Kluge 2000 modified))

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- **Development of relevant variables[7] to analyse NBS (Stage 1)**

The classification is based on the previous work of identification of the relevant variables that allows to describe (similarities-differences) and to understand the NBS. This part has already been developed in the section IV.

- **Clustering[8] the cases and analysis of empirical regularities (Stage 2)**

The clustering stage is an intermediate stage between the description (1°) and the analysis (2°).
1°/ This stage is first based on clustering the cases of NBS (primary clusters) and then to grouping the clusters themselves (secondary clusters), etc. Clusters are based on empirical regularities. The goal is to get homogeneous groups. These groups are the basis of the later types.
2°/Then an analysis aims to identify the meaning of clusters, by linking them with already identified variables (cf. stage 1), or by ensuring the emergence of new explanatory properties. In a first stage, the goal is to make visible the simple meaningful relationship between clusters. They must be compared among one another, step by step.
This stage corresponds with the identification of the analysing variables. By allowing the discrimination of the differences and similarities, it made possible to group (cluster) some types of NBS.

- **Analysis of meaningful relationship and type construction (Stage 3)**

This stage is the continuation of the previous one. At the level of the whole typology, it aims to select and to structure the analytical variables that help to understand the relationships in the typology. The emblematic visual representation of this stage is the tree view.
The selection of the explaining variables is done in accordance with the meanings of clusters. Then the variables are assembled following a defined hierarchy. This finally composes the structure of the NBS classification (the branches of the tree view).
This stage represents the construction of the structure of the typology, the architecture of the categories, the classes and sub-classes and their characterization.

- **Types[9] construction and characterization (Stage 4)**

Once the clusters are well outlined and structured, the last stage is the detailed definition and characterization of the types.
Archetypes and extreme types are defined. In N4C, the main NBS entities will be documented following a common grid, see section VI.

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7 "Variables" are also called “attributes” or “properties”.

8 "Group", "class", "cluster" can be considered as synonyms.

9 "Type" or "category"

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V.1.2 Criteria of the classification

Large spectrum	the classification must cover a large spectrum of NBS in terms of spatial scales, issues (from environmental to social ones), etc.
Accessible	the terms employed and the way of classification are supposed to be accessible to all the future users of the tools whatever their background: scientists, urban planners and practitioners, politicians, inhabitants, etc.
Discriminating	It must allow discriminating different solutions by showing differences and similarities
Flexible	The classification may evolve in future (the pioneer projects on which we work in T1.3 may provide new types)
Compact	Still covering a large spectrum and, being discriminating, the classification remains compact. It is one of the essential goal of the classification: to summarize information. This is especially important here to keep the possibility to have an integrated overview.

V.2 Structure of the NBS classification

V.2.1 The classification: a structure project-oriented

According to the systemic approach of the NBS, and the choice to develop a classification that can be shared with all urban actors, in N4C, we privilege a project-oriented structure.
Consequently, the classification doesn't prefer one specific entry such as the scale for example, but its structure is coherent with several factors, such as: (i) the urban scales, (ii) the main ways of intervention (actions or strategies), (iii) thematics, (iv) the temporal scale (life cycle approach), (v) land use and the local environmental (on the ground, on the buildings, wetlands and aquatic environments) and (vi) form and practices.
Even if the urban challenges constitute an important factor to describe the NBS, they have not been selected as a driver of the classification, because it is not a discriminating factor. Indeed, each NBS type often meets several challenges and it is a key element of the NBS definition, the systemic approach.
The classification is divided into 4 levels of subdivision: categories, sub-categories, classes and types (Figure 37).

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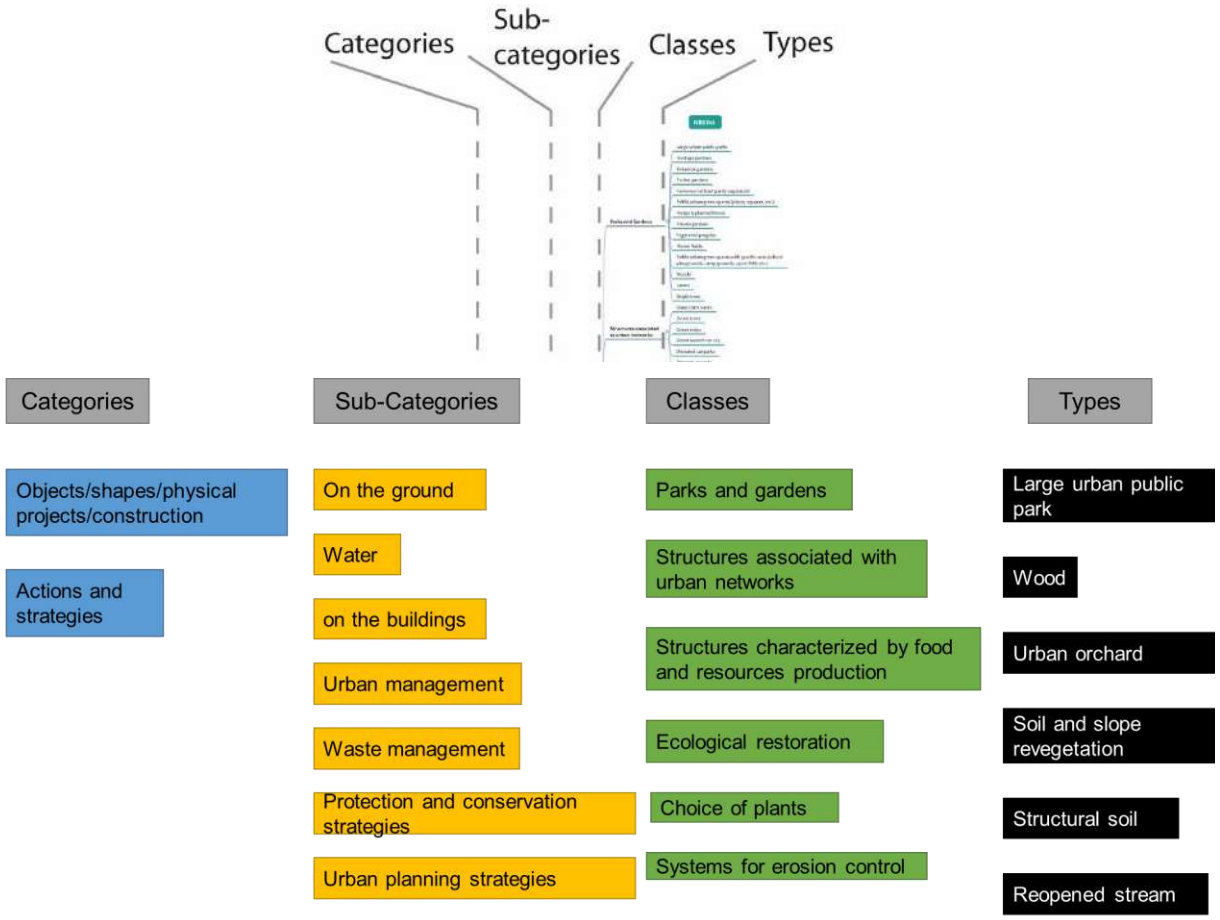

Figure 37: The 4 levels of the NBS classification (above, partial list of NBSs)

The description of each level of the NBS classification is provided as following:

Categories: There are two different clusters

Entitles of categories	Description
Objects/shapes/physical projects design/construction interventions	This category deals with material and immediately tangible solutions. These solutions can include stages of conception, but they lead to the construction, the design of an object.
Strategies, actions, management	This category deals with intangible solutions (at least immediately). The solutions refer to the projection in the life time of the object (management). They also refer to evolutions on long term or/and at large scales (urban planning).

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Entitles of categories	Entitles of sub-categories	Description
Objects/shapes/physical projects design/construction interventions	On the ground	These three sub-categories refer to different physical supports (soil cover). We chose to separate these physical supports because it makes sense from the point of view of practitioners and techniques employed. However, it is important to note that the soil, or water or habitat challenges can be tackled in all of these three sub-categories. The division doesn't concern the urban challenges.
	Water	
	On building structures	
Strategies & actions	Urban (green) spaces management	This sub-category concerns mainly the urban green spaces management but more generally the urban space. It concerns all the maintenance practises and tools (chemical, mechanized hand tools are included but also animals.) It also refers to the organization of the management and to the actor skills.
	Waste management	It refers to household waste: peelings and other food leftovers. *Nota*: Green wastes are addressed in the "Urban (green) spaces management" sub-category.
	Protection and conservation strategies	Areas, worth for protection can be assigned by different level of authorities, like local municipalities, regional authorities or national parks. Even objects, like single, old trees or methuselahs can be protected or all kinds of natural values. Strategies can limit human interventions, regulate the ways of management and the level of protection. Usually there can be find some kind of awareness-raising programs in connection with well-known protected areas.
	Urban planning strategies	Spatial planning strategies differ by each country in Europe as conditions are also diverse. However, formally or informally usually there are two types of plans: – Traditional, continental land use plans, dealing with land use, and with zoning regulation based on continental land use plans. – Development plans: aimed at the targeted interventions through fulfilling the needs in a feasible way and determining the possibilities of realisation.
	Monitoring (Bio-indicators)	Decision tools based on living organisms in order to assess and monitor an ecological state (water, soil, air) or an NBS performance

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Classes

Entitles of sub-categories	Entitles of classes	Description
On the ground	Parks and gardens	Green areas of different sizes, generally for public use, vegetated by trees, grass and other type of plants (perennial, annual plants, herbaceous)
	Structures associated with urban networks	This class refers to structures which are located on the ground associated within the urban network. They are basically large and/or long continuous green elements or areas. *Nota:* The class divides into Green tram tracks, Street trees, Green strips, Green waterfront city, Unsealed parking lot and Green parking lot.
	Structures characterized by food and resources production	This type of NBS provides tangible resources like human food production and forest or composting resources, such as vegetables and firewood, among others; furthermore, provides the expected intangible benefits of NBS, such as improving air quality, reducing the temperature. This kind of actions requires a greater involvement of citizens and city councils; which are the first beneficiaries of resources.
	Ecological restoration	This class refers to NBS that aim to restore degraded environments, and developing specific techniques for this. *Nota:* The restoration of degraded wetlands is developed in the 2 classes of the “Water” sub-category.
	Choice of plants	This class gives elements in order to build NBS with different types of vegetation and helps to take into account the different selection criteria. Nota: The choice of plant can take into account different elements (Vegetation diversification, use of pre-existing vegetation, Introduced plants).
	Systems for erosion control	This class refers to the different methods to stabilize exposed soils on slopes through revegetation in order to minimize or prevent the erosion of soil by wind or rain and avoid potential sediment problems
	Works on soil	This class relates to all the techniques that improve and optimize the performances of the urban soil. Nota: the works on soil is developed in three types: (i) soil improvement, (ii) structural soil and (iii) mulching.
Water	Natural and semi-natural water bodies and hydrographic network	This class refers to NBS that create new water bodies or restore damaged natural water bodies or streambanks, in order to maintain or recover natural habitats and an ecological continuity of the hydrographic network.
	Constructed wetlands and build	This class refers to NBS that can be implemented for water management purposes, because they

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	structures for water management	can control runoff, promote water infiltration, and filter pollutants and sediments either naturally by using soil functions or with specialised, alternative techniques for wastewater treatment.
On building & structures	Green roofs	This class refers to the different methods and intensities to cover partially or completely a building roof with vegetation and growing medium planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, increasing benevolence and decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban air temperatures and mitigate the heat island effect. Nota: The class divides into intensive, semi-intensive and extensive green roof
	Green walls	This class relates to the different vertical oriented Green walls on building structures. *Nota:* The class divides further into Climber green wall, Planter green wall and Green wall system.
Urban (green) spaces management	Direct human interventions	Maintenance practices and decisions related to a field human intervention.
	Use of fauna	Maintenance practices related to an animal field intervention (grazing for example) *Nota:* The class divides into grazing animals, insect hotel (for wild bees) and beehives (for honeybees).

V.2.2 The NBS classification

For its presentation, the NBS classification tree has been divided in the two following parts :

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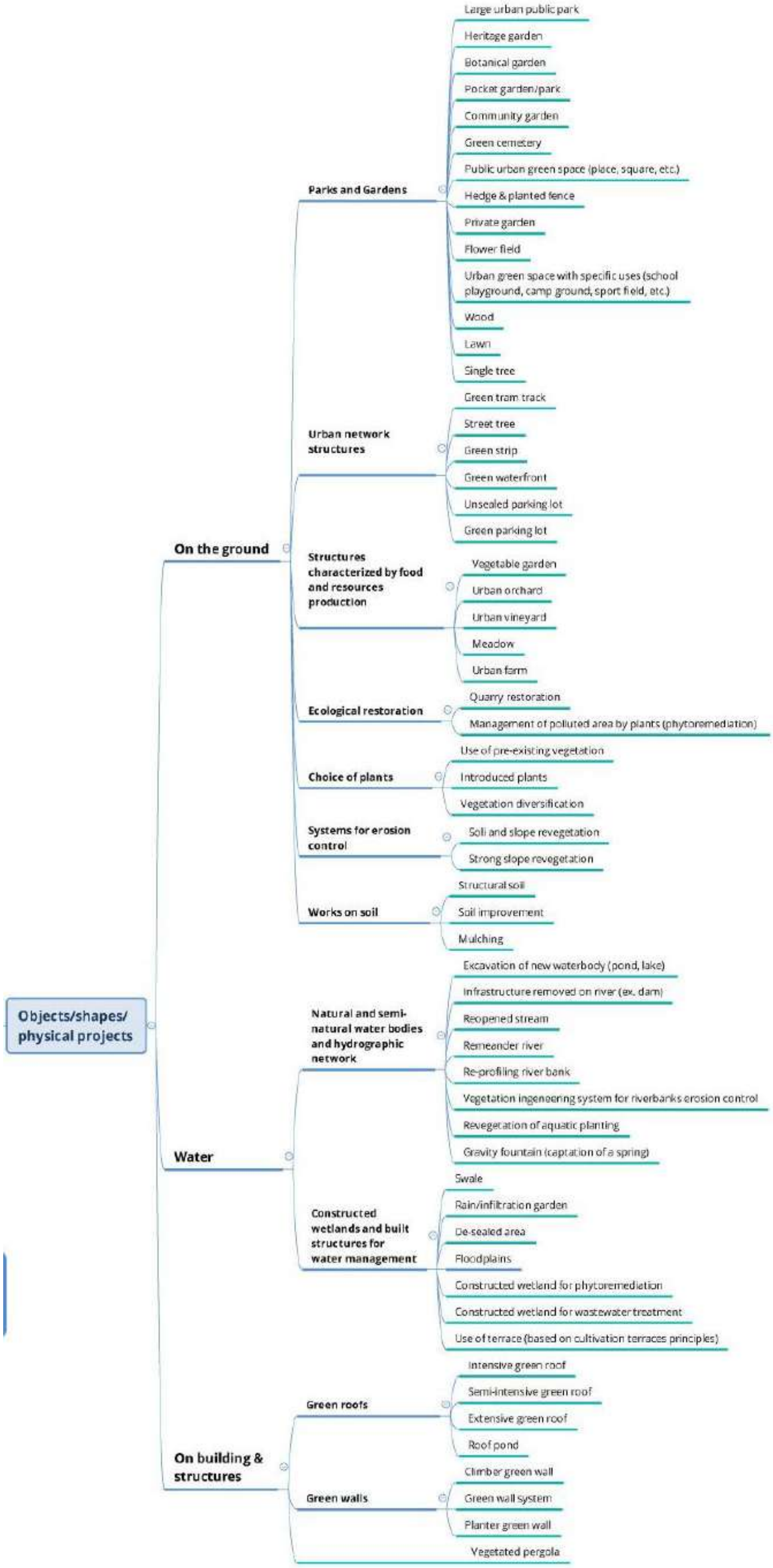

Figure 38:Part 1/2 of the NBS classification with "Objects/shapes/physical projects design/construction" interventions category

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Figure 39: Part 2/2 of the NBS classification with the "Strategies, actions, management" category

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VI. Documentation of the main NBS entities

The objective is to build a base of knowledge on the main NBS entities. This documentation targets generic information on the NBS, even if it can be illustrated by examples.
The main entities of the NBS classification have been documented in the frame of the task1.1. One of our main criteria to choose these NBS was to get a representativeness of all the sub-divisions of the classification. In the end, we have documented 53 NBS entities.
The produced factsheets constitute the heart of the knowledge base on NBS. There are based on N4C partner expertise.

VI.1 Analysis grid for the documentation of the main NBS entities

This part present the generic analysis grid used for the documentation of the main NBS entities. The grid has been adapted to all the NBS types.

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

- Definition
- Different variants existing

I.2 Urban challenges and sub-challenges related + impacts

- Main challenges and sub-challenges targeted by the NBS
- Co-benefits and challenges foreseen
- Possible negative effects

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales

- Scale at which the NBS is implemented
- Impacted scales

II.2 Temporal perspectives (including management issues)

- Expected time for the NBS to become fully effective after its implementation
- Life time
- Sustainability and life cycle
- Management aspects (kind of interventions + intensity)

II.3 Stakeholders involved/ social aspects

- Stakeholders involved in the decision process
- Technical stakeholders & networks
- Social aspects

II.4 Design / techniques/ strategy

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- Knowledge and how-know involved
- Materials involved

II.5 Legal aspects related

II.6 Funding Economical aspects

- Range of cost
- Origin of the funds (public, private, public-private, other)

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

- Success factors
- Limiting factors

III.2 Comparison with alternative solutions

- Grey or conventional solutions counterpart
- Close NBS

IV/ References

IV.1 Scientific and more operational references (presented jointly)

IV.2 Sources used in this factsheet

V/ Author(s)

Name	Institution / company	Writer/ reviewer

VI.2 NBS factsheets

Total number of NBS types identified in the typology	74
Total number of NBS types documented	59

The NBS factsheets are in Appendix 3: NBS factsheets.

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VII Conclusion

In Task1.1, the concept of "Nature-Based Solutions" (NBS) has first been discussed by comparing it to other concepts already used in reference to nature in Chapter II. The main goal of this theoretical work was to build the framework that will be the base of Nature4Cities further developments for the application of NBS concept to the urban development context.

The theoretical concept has been then confronted with practical examples so that to discuss the arguments to decide whether the case can be classified as a NBS. In doing that, we achieved three of our goals: to confront the NBS concept with concrete cases (Chapter III), to build a NBS list and to build an analysis grid to read and analyse the NBS (Chapter IV).

In chapter V, we developed the classification work from the conclusion of the different considerations brought by the previous developments. This resulted in an operational classification, designed to structure the NBS inventory in a way that facilitates a recursive search in the NBS database, using operational entries. Built on both the nature of the NBS and the urban challenges they answer, it is a mutli-thematic typology. It is based on the form of intervention (forms or strategies) and on the support of the NBS (water, ground or building). The typology is also multi-scalar, the NBS being classified by their scale (city, neighbourhood or entity).

Finally, having built the classification and the list of NBS, a specific work has been carried out to produce a useful documentation of NBS generic entities. The first stage was to build a common documentation grid and then document each NBS in factsheets that forms the NBS database. This stages is described in Chapter VI.

By developing theoretical aspects of the NBS concept, by identifying and structuring NBS in a typology and by developing a NBS database, this deliverable meets different important challenges.

For the N4C project itself:

Beyond the theoretical aspects this work leads to two kinds of contributions: the typology structure and the NBS database. Both of them will be used in the other WPs and tasks. This work was carried out collectively and widely shared in the project so that to share a common knowledge absolutely necessary to the good continuation of the project. Indeed, part of the partners were not accustomed to deal with NBS and the fact to be implied in the documentation or review of NBS factsheets allowed them to question the notion and the way to define NBS. It is closed or it is a work in progress that will be updated and revised during the project?

For the general understanding of the NBS:

As we noted in this work, the NBS is a recent concept. And even if more and more references are dealing with it, the literature on NBS still remains limited. We hope so that this work will extend the knowledge both on theoretical and on practical aspects.

However, we are also aware that some aspects will require further investigations. Ourselves, we plan to develop more this work in a scientific publication implying the main contributors of these specific developments.

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VIII. References

Ahern, Jack. 2007. “Green Infrastructure for Cities: The Spatial Dimension. In.” In Cities of the Future: Towards Integrated Sustainable Water and Landscape Management. IWA Publishing. Citeseer.

Albert, Christian, Joachim H. Spangenberg, and Barbara Schröter. 2017. “Nature-Based Solutions: Criteria.” Nature, Correspondence, 543 (7645): 315.

Barton, Melissa Alane. 2016. “Nature-Based Solutions in Urban Contexts - A Case Study of Malmö, Sweden.” Master Thesis report. Lund, Sweden: The International Institute for Industrial Environmental Economics (IIIEE), Lund University.

Baumgartl, Th. 1998. “Physical Soil Properties in Specific Fields of Application Especially in Anthropogenic Soils.” Soil and Tillage Research 47 (1): 51–59. https://doi.org/10.1016/S0167-1987(98)00072-5.

Béchet, B, F Carré, L Florentin, C Leyval, L Montanarella, JL Morel, G Raimbault, F Rodriguez, JP Rossignol, and C Schwartz. 2009. “Caractéristiques et Fonctionnement Des Sols Urbains.” Cheverry et Gascuel (Éd) Sous Les Pavés La Terre, Omniscience, Montreuil, 45–74.

Blanchart, Anne, Geoffroy Sere, Johan Cherel, Gilles Warot, Marie Stas, Jean Noël Consales, and Christophe Schwartz. 2017. “Contribution Des Sols à La Production de Services Écosystémiques En Milieu Urbain–une Revue.” Environnement Urbain/Urban Environment, no. Volume 11.

Castrignanò, A, L Giugliarini, R Risaliti, and N Martinelli. 2000. “Study of Spatial Relationships among Some Soil Physico-Chemical Properties of a Field in Central Italy Using Multivariate Geostatistics.” Geoderma 97 (1–2): 39–60.

Cohen-Shacham, E., G. Walters, C. Janzen, and S. Maginnis, eds. 2016. Nature-Based Solutions to Address Global Societal Challenges. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en.

Costanza, Robert. 2008. “Ecosystem Services: Multiple Classification Systems Are Needed.” Biological Conservation 141 (2): 350–52. https://doi.org/10.1016/j.biocon.2007.12.020.

Costanza, Robert, Ralph d’Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, et al. 1997. “The Value of the World’s Ecosystem Services and Natural Capital.” Nature 387 (May): 253.

Costanza, Robert, and Ida Kubiszewski. 2012. “The Authorship Structure of ‘Ecosystem Services’ as a Transdisciplinary Field of Scholarship.” Ecosystem Services 1 (1): 16–25. https://doi.org/10.1016/j.ecoser.2012.06.002.

Editorial Nature. 2017. “Natural Language.” Nature 541 (7644): 133.

Eggermont, Hilde, Estelle Balian, José Manuel N. Azevedo, Victor Beumer, Tomas Brodin, Joachim Claudet, Bruno Fady, et al. 2015. “Nature-Based Solutions: New Influence for Environmental Management and Research in Europe Nature-Based Solutions, an Emerging Term.” GAIA 24 (4): 243–48. https://doi.org/10.14512/gaia.24.4.9.

Elman, Colin. 2009. “Explanatory Typologies in Qualitative Analysis1.” In The SAGE Handbook of Case-Based Methods, edited by David Byrne and Charles C. Ragin, 1st ed., 121–31. SAGE.

European Commission. 2015. “Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions & Re-Naturing Cities - Final Report of the Horizon 2020 Expert Group on ‘Nature-Based Solutions and Re-Naturing Cities.’” Brussels: European Commission. http://www.gppq.fct.pt/h2020/_docs/brochuras/env/nature-based_solutions_and_re-naturing_cities.pdf.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730468

———. 2017. “Nature-Based Solutions.” European Commission website. Policy Topics Nature-Based Solutions. September 2017. https://ec.europa.eu/research/environment/index.cfm?pg=nbs.
Frank, Susanne, Christine Fürst, Lars Koschke, and Franz Makeschin. 2012. “A Contribution towards a Transfer of the Ecosystem Service Concept to Landscape Planning Using Landscape Metrics.” Challenges of Sustaining Natural Capital and Ecosystem Services 21 (October): 30–38. https://doi.org/10.1016/j.ecolind.2011.04.027.
Fuhlendorf, Samuel D, and Fred E Smeins. 1996. “Spatial Scale Influence on Longterm Temporal Patterns of a Semi-Arid Grassland.” Landscape Ecology 11 (2): 107–113.
Geneletti, Davide, and Linda Zardo. 2016. “Ecosystem-Based Adaptation in Cities: An Analysis of European Urban Climate Adaptation Plans.” Land Use Policy 50 (January): 38–47. https://doi.org/10.1016/j.landusepol.2015.09.003.
Gulsrud, Natalie Marie, Kelly Hertzog, and Ian Shears. 2018. “Innovative Urban Forestry Governance in Melbourne?: Investigating ‘Green Placemaking’ as a Nature-Based Solution.” Environmental Research 161 (February): 158–67. https://doi.org/10.1016/j.envres.2017.11.005.
Kabisch, Nadja, Niki Frantzeskaki, Stephan Pauleit, Sandra Naumann, McKenna Davis, Martina Artmann, Dagmar Haase, et al. 2016. “Nature-Based Solutions to Climate Change Mitigation and Adaptation in Urban Areas: Perspectives on Indicators, Knowledge Gaps, Barriers, and Opportunities for Action.” Ecology and Society 21 (2).
Keesstra, Saskia, Joao Nunes, Agata Novara, David Finger, David Avelar, Zahra Kalantari, and Artemi Cerdàh. 2018. “The Superior Effect of Nature Based Solutions in Land Management for Enhancing Ecosystem Services.” Science of The Total Environment 610–611: 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077.
Kluge, Susann. 2000. “Empirically Grounded Construction of Types and Typologies in Qualitative Social Research.” Forum Qualitative Sozialforschung / Forum: Qualitative Social Research 1 (1).
Krummel, JR, RH Gardner, G Sugihara, RV O’neill, and PR Coleman. 1987. “Landscape Patterns in a Disturbed Environment.” Oikos, 321–324.
Lang, Jon. 2005. Urban Design - A Typology of Procedures and Products. Architectural Press (Elsevier). Oxford.
Lawrence, Anna, Rik De Vreese, Mark Johnston, Cecil C. Konijnendijk van den Bosch, and Giovanni Sanesi. 2013. “Urban Forest Governance: Towards a Framework for Comparing Approaches.” Urban Forestry & Urban Greening 12 (4): 464–73.
Lenzholzer, Sanda. 2008. “A City Is Not a Building – Architectural Concepts for Public Square Design in Dutch Urban Climate Contexts.” Journal of Landscape Architecture 3 (1): 44–55. https://doi.org/10.1080/18626033.2008.9723395.
Lutter, S, and S Giljum. 2008. Development of RACER Evaluation Framework. 7 October 2008. ERA-NET SKEP Project EIPOT (Development of a Methodology for the Assessment of Global Environmental Impacts of Traded Goods and Services).
Maes, Joachim, and Sander Jacobs. 2015. “Nature-Based Solutions for Europe’s Sustainable Development.” Conservation Letters 10 (1): 121–24.
Maes, Joachim, Grazia Zulian, Martijn Thijssen, Carles Castell, Francesc Baró, Ana Margarida Ferreira, João Melo, and & al. 2016. “Mapping and Assessment of Ecosystems and Their Services - Urban Ecosystems 4th Report.” Technical report 4th. Luxembourg: Office of the European Union.
McClintock, Nathan. 2012. “Assessing Soil Lead Contamination at Multiple Scales in

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730468

Oakland, California: Implications for Urban Agriculture and Environmental Justice." Applied Geography 35 (1): 460–73.
McGarigal, Kevin, Sam A Cushman, Maile C Neel, and Eduard Ene. 2002. "FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps."
McGrath, Daniel T. 2005. "More Evidence on the Spatial Scale of Cities." Journal of Urban Economics 58 (1): 1–10.
Millenium Ecosystem Assessment. 2003. "Ecosystems and Human Well-Being: A Framework for Assessment." Island Press, Washington DC.
———. 2005. "Ecosystems and Human Well-Being: Synthesis." Island Press, Washington, DC.
Nesshöver, Carsten, Timo Assmuth, Katherine N. Irvine, Graciela M. Rusch, Kerry A. Waylen, Ben Delbaere, Dagmar Haase, et al. 2017. "The Science, Policy and Practice of Nature-Based Solutions: An Interdisciplinary Perspective." Science of The Total Environment 579: 1215–27.
Oke, T. R. 2006. "Towards Better Scientific Communication in Urban Climate." Theoretical and Applied Climatology 84 (1–3): 179–90. https://doi.org/10.1007/s00704-005-0153-0.
Potschin, Marion, Conor Kretsch, Roy Haines-Young, Eeva Furman, Pam Berry, and Francesc Baró. 2016. "Nature-Based-Solutions." In OpenNESS Ecosystem Services Reference Book. http://www.openness-project.eu/sites/default/files/SP_Nature-based-solutions.pdf.
Raymond, Christopher M., Pam Berry, Margaretha Breil, Mihai R. Nita, Nadja Kabisch, Mark De Bel, Vera Enzi, et al. 2017. "An Impact Evaluation Framework to Support Planning and Evaluation of Nature-Based Solutions Projects. Report Prepared by the EKLIPSE Expert Working Group on Nature-Based Solutions to Promote Climate Resilience in Urban Areas." Wallingford, United Kingdom: Centre for Ecology & Hydrology.
Rey, Freddy, Frédéric Gosselin, and Antoine Dore. 2014. Ingénierie Écologique – Action Par et/Ou Pour Le Vivant? Quae. Versailles.
Schaubroek, Thomas. 2017. "Nature-Based Solutions: Sustainable?" Nature, Correspondence, 543 (7645): 315.
Shackleton, C. M., S. Ruwanza, G. K. Sinasson Sanni, S. Bennett, P. De Lacy, R. Modipa, N. Mtati, M. Sachikonye, and G. Thondhlana. 2016. "Unpacking Pandora's Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing." Ecosystems 19 (4): 587–600.
Turner, Monica Goigel. 1989. "Landscape Ecology: The Effect of Pattern on Process." Annual Review of Ecology and Systematics 20 (1): 171–197.
Urban Dean L. 2005. "Modeling Ecological Processes across Scales." Ecology 86 (8): 1996–2006. https://doi.org/10.1890/04-0918.
Wallace, Ken J. 2007. "Classification of Ecosystem Services: Problems and Solutions." Biological Conservation 139 (3): 235–46.
Zardo, L., D. Geneletti, M. Pérez-Soba, and M. Van Eupen. 2017. "Estimating the Cooling Capacity of Green Infrastructures to Support Urban Planning." Ecosystem Services 26 (August): 225–35. https://doi.org/10.1016/j.ecoser.2017.06.016.
Zhao, Yongcun, Zhigang Wang, Weixia Sun, Biao Huang, Xuezheng Shi, and Junfeng Ji. 2010. "Spatial Interrelations and Multi-Scale Sources of Soil Heavy Metal Variability in a Typical Urban–rural Transition Area in Yangtze River Delta Region of China." Geoderma 156 (3): 216–27.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

OECD, 2005, Statistical Definition of Biotechnology, OECD website: URL: [http://www.oecd.org/sti/inno/statisticaldefinitionofbiotechnology.htm], consulted the 25th January 2018.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

IX Appendices

Appendix 1: Definition of Nature-based Solutions by the European Commission (2015)

Here is the complete definition proposed by the European Commission (2015) in the report "Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities - Final Report of the Horizon 2020 Expert Group", annex 1, page 25.

> "Nature-based solutions aim to help societies address a variety of environmental, social and economic challenges in sustainable ways. They are actions inspired by, supported by or copied from nature; both using and enhancing existing solutions to challenges, as well as exploring more novel solutions, for example, mimicking how non-human organisms and communities cope with environmental extremes. Nature-based solutions use the features and complex system processes of nature, such as its ability to store carbon and regulate water flows, in order to achieve desired outcomes, such as reduced disaster risk and an environment that improves human well-being and socially inclusive green growth. This implies that maintaining and enhancing natural capital is of crucial importance, as it forms the basis for solutions. These nature-based solutions ideally are resilient to change, as well as energy and resource efficient, but in order to achieve these criteria, they must be adapted to local conditions.
> The "nature-based solution" concept builds on and supports other closely related concepts, such as the ecosystem approach, ecosystem services, ecosystem-based adaptation/mitigation, and green and blue infrastructure. They all recognise the importance of nature and require a systemic approach to environmental change based on an understanding of the structure and functioning of ecosystems, including human actions and their consequences. Nature-based solutions, however, have a distinctive set of premises: (i) some societal challenges stem from human activities that have failed to recognize ecological limitations; (ii) sustainable alternatives to those activities can be found by looking to nature for design and process knowledge. They therefore involve the innovative application of knowledge about nature, inspired and supported by nature, and they maintain and enhance natural capital. They are positive responses to societal challenges, and can have the potential to simultaneously meet environmental, social and economic objectives.
> There has been much debate over the components of nature-based solutions and, within the current EU framework, nature-based solutions exclude methods that artificially alter nature, such as genetically modified organisms."

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Appendix 2: Urban challenges

Cf. Tables produced by LIST in the work entitled “Initial identification of the urban challenges”

1) Climate mitigation and adaptation; 2) Water management; 3) Coastal resilience; 4) Green space management (including enhancing/conserving urban biodiversity); 5) Air/ambient quality; 6) Urban regeneration; 7) Participatory planning and governance; 8) Social justice and social cohesion; 9) Public health and well-being; 10) Potential for new economic opportunities and green jobs.		1) Water security 2) Food security 3) Human health 4) Disaster risk reduction 5) Climate change
Eklipse		IUCN

Challenges of the HQE2R circles for sustainability (proposed in the frame of the EU research program “Sustainable renovation of buildings for sustainable neighbourhood (HQE²R)” (2001-2004):

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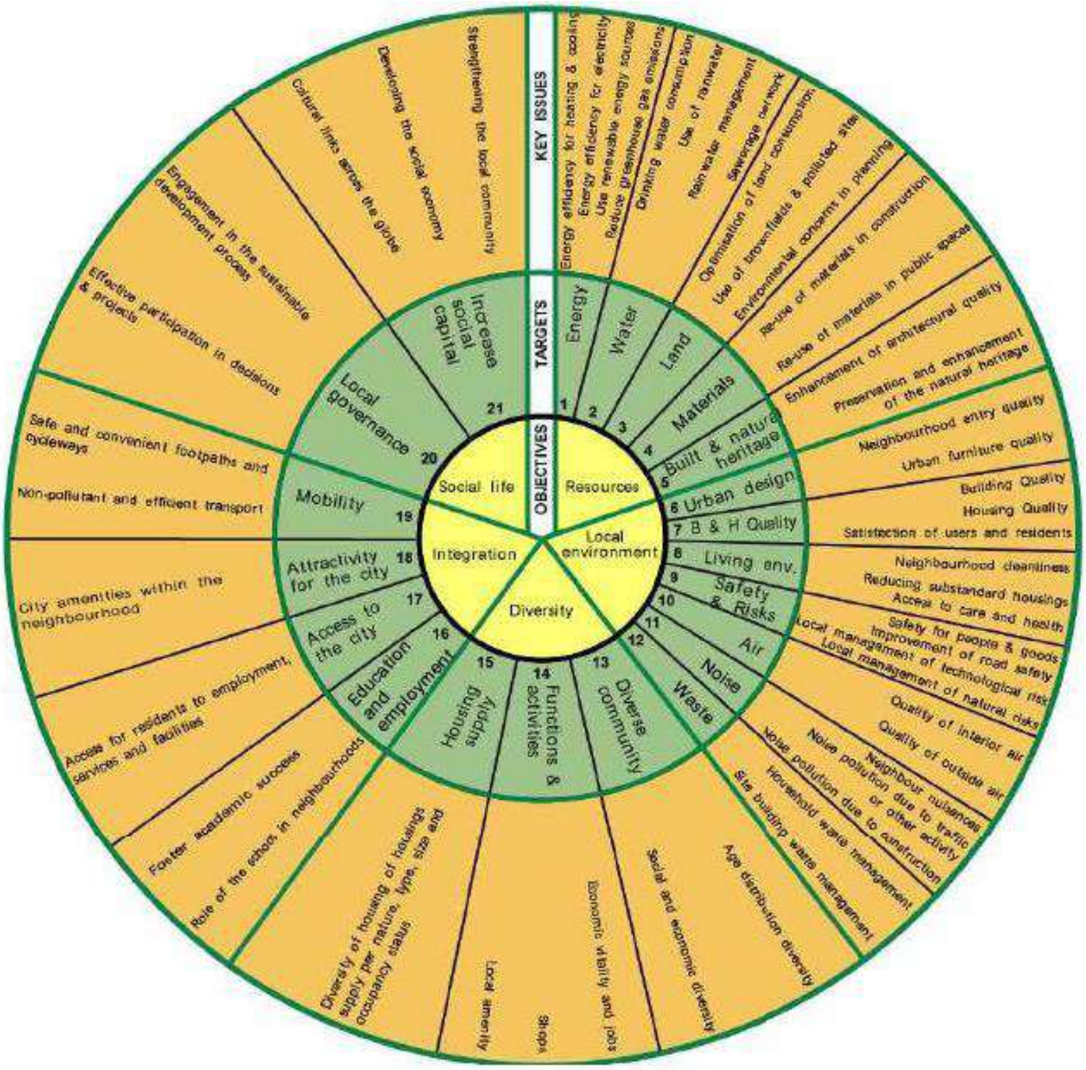

Figure 40: Challenges identified in a study produced by the WWF (http://wwf.panda.org/what_we_do/footprint/one_planet_cities/urban_solutions/themes_new/)

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Figure 41: Challenges by WWF

Figure 42: challenges treated in Urbact project. http://urbact.eu/sustainablecities.net

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Appendix 3: NBS factsheets

56 NBS have been documented by N4C partners, the resulting factsheets are gathered in this appendix. The list of these entities and how they complete the typology is given in the next figure.

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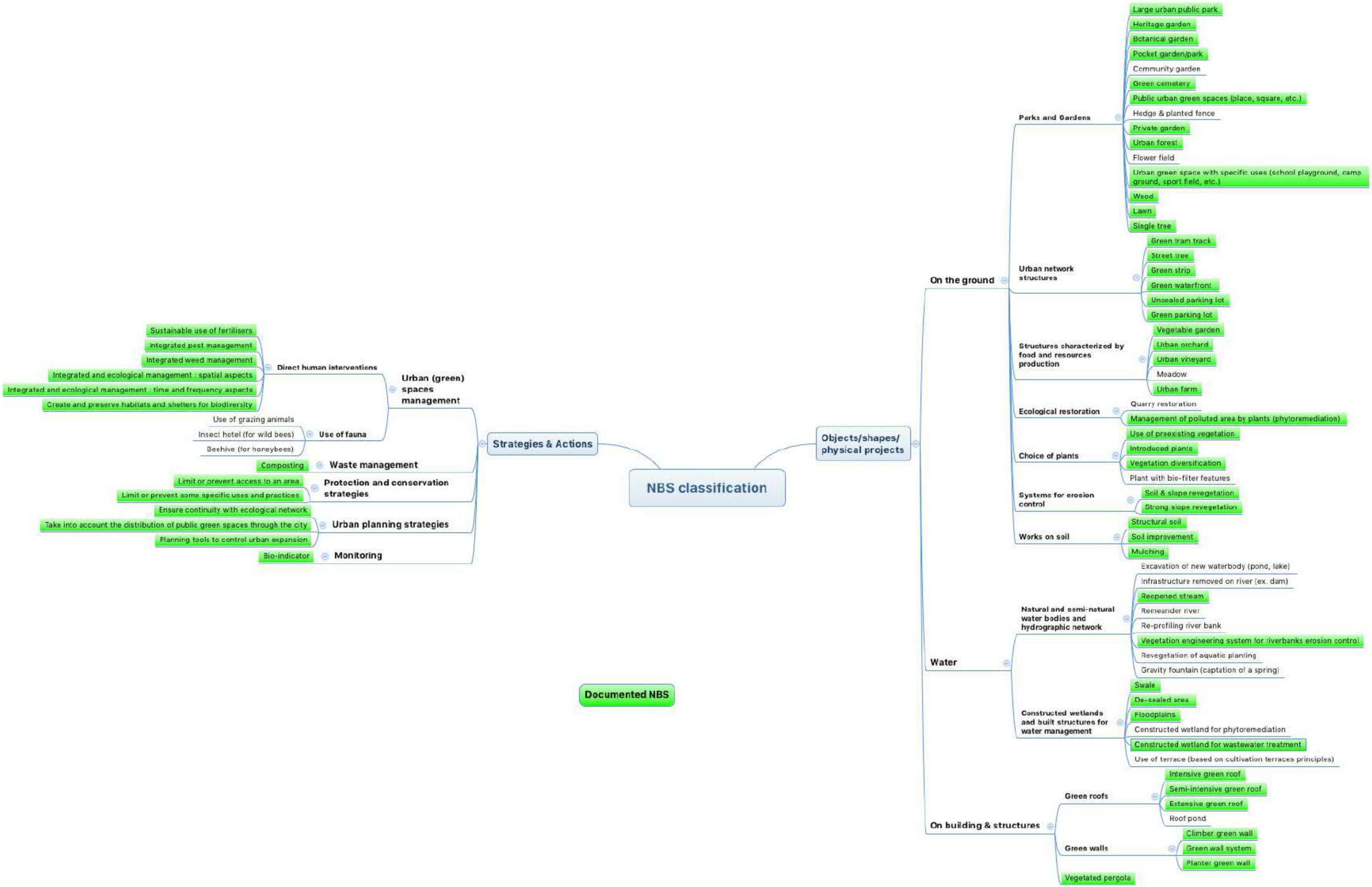
NBS classification
Objects/shapes/ physical projects
On the ground
Parks and Gardens
Large urban public park
Heritage garden
Botanical garden
Pocket garden/park
Community garden
Green cemetery
Public urban green spaces (place, square, etc.)
Hedge & planted fence
Private garden
Urban forest
Flower field
Urban green space with specific uses (school playground, camp ground, sport field, etc.)
Wood
Lawn
Single tree
Urban network structures
Green tram track
Street tree
Green strip
Green waterfront
Unsealed parking lot
Green parking lot
Structures characterized by food and resources production
Vegetable garden
Urban orchard
Urban vineyard
Meadow
Urban farm
Ecological restoration
Quarry restoration
Management of polluted area by plants (phytoremediation)
Choice of plants
Use of preexisting vegetation
Introduced plants
Vegetation diversification
Plant with bio-filter features
Systems for erosion control
Soil & slope revegetation
Strong slope revegetation
Works on soil
Structural soil
Soil improvement
Mulching
Water
Natural and semi-natural water bodies and hydrographic network
Excavation of new waterbody (pond, lake)
Infrastructure removed on river (ex. dam)
Reopened stream
Remeander river
Re-profiling river bank
Vegetation engineering system for riverbanks erosion control
Revegetation of aquatic planting
Gravity fountain (captation of a spring)
Constructed wetlands and built structures for water management
Swale
De-sealed area
Floodplains
Constructed wetland for phytoremediation
Constructed wetland for wastewater treatment
Use of terrace (based on cultivation terraces principles)
On building & structures
Green roofs
Intensive green roof
Semi-intensive green roof
Extensive green roof
Roof pond
Green walls
Climber green wall
Green wall system
Planter green wall
Vegetated pergola
Strategies & Actions
Urban (green) spaces management
Direct human interventions
Sustainable use of fertilisers
Integrated pest management
Integrated weed management
Integrated and ecological management : spatial aspects
Integrated and ecological management : time and frequency aspects
Create and preserve habitats and shelters for biodiversity
Use of fauna
Use of grazing animals
Insect hotel (for wild bees)
Beehive (for honeybees)
Waste management
Composting
Protection and conservation strategies
Limit or prevent access to an area
Limit or prevent some specific uses and practices
Urban planning strategies
Ensure continuity with ecological network
Take into account the distribution of public green spaces through the city
Planning tools to control urban expansion
Monitoring
Bio-indicator
Documented NBS

Objects/shapes/ physical projects

- **On the ground**
- **Water**
- **On buildings and structures**

➢ On the ground

➢ Parks and Gardens

> BOTANICAL GARDEN

> GREEN CEMETRIES

> HERITAGE GARDEN

> LARGE URBAN PUBLIC PARK

> LAWN

> POCKET GARDEN

> PRIVATE GARDEN

> URBAN FOREST

> PUBLIC URBAN GREEN SPACES

> SINGLE TREE

> URBAN GREEN SPACE WITH SPECIFIC USES

> URBAN FOREST

> WOOD

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	A botanic garden is a public institution holding documented collections of well-tended living plants for the purposes of scientific research, conservation, display and education (Botanic Gardens Conservation International, BGCI). This distinguishes them from parks where plants are grown for public welfare only. Botanical gardens should have a complete documentation of their collections, control over collected plants and should demonstrate responsible management of their collections.

Different variants existing

The major types of botanic gardens are (according to Wise, 2000):

1. 'Classic' multi-purpose gardens: horticulture and horticultural training; public education; research in taxonomy with associated herbaria; generally state supported
2. Ornamental gardens: diverse, documented plant collections; in some cases, research, education or plant conservation; privately owned or municipally owned
3. Historical botanic gardens (medicinal plants): active medicinal plant collection and cultivation; research
4. Conservation gardens: plant conservation; some of them are native plant gardens; public education
5. University gardens: university maintained for teaching and research; often open to public
6. Combined botanical and zoological gardens: plants collections are researched and developed that provide habitats for the displayed fauna; interpretation to the general public
7. Agro-botanical and germplasm gardens: collection of plants of economic value or potential for conservation; research; plant breeding and seed testing facilities; generally not open to public
8. Alpine or mountain gardens: in mountain regions of Europe: cultivation of mountain and alpine flora, in some tropical countries; cultivation of subtropical or temperate flora
9. Natural or wild gardens: natural or semi-natural vegetation, which is protected and managed; native plants; plant conservation and public education roles
10. Horticultural gardens: foster the development of horticulture through the training of gardeners; plant breeding; conservation of garden plant varieties; owned by horticultural societies; often open to public
11. Thematic gardens: a limited range of related or morphologically similar plants (orchid, rose, bamboo) or they illustrate a particular theme (ethnobotany, medicine, bonsai, topiary, butterfly gardens, carnivorous plants and aquatics) in support of education, science, conservation and public display
12. Community gardens: small gardens with limited resource; developed for, and by, a local community to fulfil its needs (recreation, education, conservation, horticultural training); growth of medicinal and other economic plants

Alpine garden in the botanical garden of Darmstadt, Germany
https://www.botanischer-garten.org

Zoo & Botanical Garden, Budapest, Hungary
© Lugosi Dániel

Rose garden in Thematic Gardens Hortulus in Dobrzyca, Poland
http://www.hortulus.evroturizm.eu/

Collected plants diversity: most botanical gardens specialize in their own region's plants, however they may contain special plant collections such as cacti, tropical plants, exotic plants, alpine plants, herb gardens, medicinal plants, plants from particular parts of the world
Other amenities: there may be greenhouses, shadehouses, test grounds and other departments

Botanical gardens that specialize in woody plants (shrubs and trees) are often referred to as arboretums.

Jardin des Plantes, a botanical garden in Paris, France
http://www.jardindesplantes.net

Tropical greenhouse in Jardin des Plantes, botanical garden in Paris, France
© MNHN – FG Grandin

Arboretum in Szarvas, Hungary
https://www.historicgarden.net

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate adaptation > 01-2 Climate mitigation 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 07| Public health and well-being > 07-2 Acoustics > 07-2 Quality of life > 07-3 Health 08| Environmental justice and social cohesion > 08-1 Environmental justice > 08-2 Social cohesion	- carbon sequestration - reducing the temperature and regulating the microclimate at neighbourhood and object scale (localized warming) by evapotranspiration and shading - supporting a wide range of plants (native plants and special plant collections), preserving and applying plant diversity, conserving plant, long-term maintenance - habitat for insects and birds - connecting green spaces - acting on sound propagation and perception - increasing physical activity, well-being, and improving/supporting health, moderating stress - providing leisure and recreation facilities (relaxing, casual strolls, horticultural exhibitions, plant sales, theatrical and musical performances) - aesthetic value - arboretum: noise shielding - cognitive development, improvement of opportunities for exploration by children (reconnect children with nature) - education, environmental education (summer camps for kids, school group tours, interpretation, classes and seminars) - scientific research (from molecular research in the lab to ecological field work; publications) - facilitating social interaction and community attachment, promoting social cohesion
Co-benefits and challenges foreseen	02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 03| Air quality 09| Urban planning and governance > 09-1 Urban planning and form 11| Green economy > 11-3 Direct economic value of NBS	- intercepting of stormwater and reducing run-off - absorbing particles and pollutants - increasing amount of green open space for residents, increasing cultural richness and diversity in urban areas - attractive to tourists (are among their motivations to visit certain regions/cities) - delivering multiple economic benefits, e.g. large job opportunities, increasing the value of close properties, increasing tax revenues
Possible negative effects	-	-

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	District/Neighbourhood scale
Impacted scales	- Object, District/Neighbourhood - City: some impacts take a wider area than the one where the NBS is implemented, e.g. climate of the whole city, well-being of inhabitants, social interaction
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Usually 1-5 years, it depends on the establishment and development of plants and amenities. Considering the growth of trees, it could be longer: 10-15 years. Some of its benefits (e.g. significant air quality change, social and health benefits) will take longer than 5 years to be fully realised.
Life time	More than 10 years – it depends on species, control over and responsible management of the collections, as well as resource depletion coming from human activities
Sustainability and life cycle	Botanical gardens are active in the sustainable use of biodiversity. Professional selection and use of plants in botanic gardens could provide environmental, social, and ecological options for urban brownfield redevelopment into green areas (Smetana and Crittenden, 2014). Botanical gardens maintain extensive collections and undertake research on useful plants with actual or potential value for food, agriculture, forestry, horticulture, ecological purposes (such as habitat management, restoration and reintroduction, land reclamation, soil improvement and stabilisation), amenity (display, tourism, recreation), essential oils, fuel, medicinal plants, forage and many other purposes (Wise, 2000) Botanical gardens are also active in monitoring domestic and international damaging or potentially unsustainable trade in plants and produces (Wise, 2000). The general life cycle is long in case of correct maintenance, but it depends on the chosen plants. Some well-managed tree species are maintained more than 100 years. However, some plants are replaced annually, their life cycle is expanded only to the vegetation period of a certain year.
Management aspects (kind of interventions + intensity)	Considering all interventions: almost daily intervention (current tasks, highly dependent on current weather and season/month) Maintenance of areas: - landscaping, mowing, flower and tree planting, grooming, pesticide and herbicide applications, weeding, hoe work, irrigation, raising of saplings, pruning, cut branches, removing trees and shrubs, processing fallen and dehydrated trees, removing leaf litter, suppressing invasive plants, wild protection - establishment, maintenance or removal of greenhouses, benches, fountains, drinking fountains, playgrounds, and other departments - maintenance of automatic irrigation systems

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	Relies on partnerships and communication between: owners, co-owners, national and local government, managers
Technical stakeholders & networks	Relies on partnerships and communication between (some of them): horticulturists and gardeners, educational institutions, research institutes, urban planners, designers, landscape architects, ecologists, local green spaces managers, nonprofit organizations
Social aspects	- implementation, management and maintenance of botanical gardens: the residents and the students do not only use the green spaces but can be active

	partners in them. It is important to increase their involvement in these activities, which require awareness campaigns and trainings. - education, environmental education (summer camps for kids, school group tours, interpretation, classes and seminars) - periodic programmes to promote public understanding of biodiversity, its importance and loss - scientific research (from molecular research in the lab to ecological field work) and publications in many relevant fields, such as taxonomy, ecology, biochemistry, ethnobotany, education, horticulture, plant anatomy, biogeography

University students are working during a summer camp, in Arboretum, Szarvas, Hungary
http://www.newjsag.hu

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- the nature of the surrounding environment - land use needs, garden use - area requirements for the number of visitors - knowledge of local climate conditions - selection of plants - select the most suitable support system (woods, amenities) - recreation management (Chan et al., 2018) - continuous monitoring of garden conditions (Chan et al., 2018) - monitoring of the plants in the collection
Materials involved	Wide range of materials due to the wide range of vegetation and amenities. In terms of impact, the vegetation, the pavement materials, the materials of the garden buildings, and the decorative features have the largest significance, which is very widespread.

II.5 Legal aspects related

They rely on national/municipal laws, e.g. urban structure plan, urban building regulations, urban development laws, concepts, strategies, park master plan, land use planning regulation.
Many countries have developed national legislation and/or national strategies and action plans on biodiversity/nature conservation and environmental protection.
Special policies and legislations relevant to botanical gardens: United Nations Convention on Biological Diversity (CBD), The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

II.6 Funding Economical aspects

Range of cost	It highly depends on its size, plants, amenities and several local contexts. The expense includes administration, maintenance security and energy, plant research and conservation, horticulture, education and outreach, special fundraising events, exhibitions, general fundraising, and earned income activities cost. In the case of New York Botanical Garden, in 2016, the expense was $72.6 million *(https://www.nybg.org)*

Origin of the funds (public, private, public-private, other)	Public, Private, or Public-private partnerships The origin of the funds can be (some of them): national and local government funding, multi-agency public sector funding (range of government departments and agencies), universities and other educational institutes, research institutes, marketing income, entrance ticket, revenue-raising public entertainment facilities (music, art exhibitions, special botanical exhibitions, theatre, film, etc.), donations from private individuals and corporations, national/local historical commissions, nonprofit organizations, conservancies, private foundations, community foundations, company-based foundations

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Some of them can be available in botanical gardens:
- environmental friendly solutions: hedge and planted fences, vegetated pergolas, flower beds and fields, lawn, water bodies, fountains, green roofs, climber green walls, living walls systems, build or attached planter systems, permeable pavement, irrigation systems
- conventional solutions: several types of pavement

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	- overall character of the city - role in the settlement structure - nature of the surrounding environment - location, accessibility, connection to the neighbourhoods (distance, road access) - transport links, surrounding traffic intensity - total size of the area - attendance periodicity, visitor density - area requirements for the number of visitors - proper amenities - keeping competitive weeds out of the garden - sustainable irrigation system - selection of plants - adequate labelling of the plants - avoid overuse (vehicles, littering, carving on trees, vandalism, pickpocket) - the recreation management (Chan et al., 2018) - the continuous monitoring of garden conditions (Chan et al., 2018) - monitoring of the plants in the collection - widespread ecosystem services (leisure, recreation, environmental education, etc.) for everyone - appropriate conditions for socializing - acceptance of the locals, popular pastime
Limiting factors	- problems deriving from excessive use of the public, e.g. littering, carving on trees, vandalism, pickpocket. It may cause resource depletion and user conflicts (Chan et al., 2018) - low prioritization, an ineffective public sector, budgetary constraints - better standard of documentation of living collections and resources to develop a global information system on botanical collections are required (http://www.bgci.org) - urgently in need of financial and other forms of technical support and resources (http://www.bgci.org) - new training and study opportunities are required for scientists, horticulturists and botanic garden managers (http://www.bgci.org) - challenges associated with lack of expertise in general and participatory management of botanical garden maintenance

	- the complexity in planning and implementing botanical gardens, for example, differing property ownership and competition demands, neglecting multi-functionality - inadequate communication and focus on ecosystem disservices - the complex synergies between NBS, governance and community engagement processes at an operational and financial level (Raymond et al., 2017)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Urban brownfield land, empty open space, concrete pavement, lawn
Close NBS	- large urban public parks, public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), green cemeteries, heritage gardens, pocket gardens, private gardens, urban fam, urban vineyard, vegetable gardens, urban orchards - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems - composting, mulching - use of fauna

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- Bull, G. (ed): Green Infrastructure. An integrated approach to land use. Landscape Institute, London, UK
- Cannon, C.H., Kua, C-S. (2017): Botanic gardens should lead the way to create a “Garden Earth” in the Anthropocene. Plant Diversity 39, 331–337
- Cvejic, R., Eler, K., Pintar, M., et al. (2015): A typology of urban green spaces, ecosystem provisioning services and demands. Report of EU FP7 (ENV.2013.6.2-5-603567) GREEN SURGE project (2013-2017)

IV.2 Sources used in this factsheet

- BGCI, Botanic Gardens Conservation International, article, December 1999: https://www.bgci.org/resources/article/0080/
- Chan, C-S., Si, F.H., Marafa, L.M. (2018): Indicator development for sustainable urban park management in Hong Kong. Urban Forestry & Urban Greening 31, 1–14
- New York Botanical Garden, Consolidated Financial Statements: https://www.nybg.org/content/uploads/2017/04/NYBG-2016-Audit-Rpt.pdf
- Raymond, C.M., Berry, P., Breil, M., et al. (2017): An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom
- Smetana, S., Crittenden, J.C. (2014): Sustainable plants in urban parks: A life cycle analysis of traditional and alternative lawns in Georgia, USA. Landscape and Urban Planning 122, 140–151
- Wyse Jackson, P.S., Sutherland, L.A. (2000): International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International, U.K.

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Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Green cemeteries refer to burial ground often covered by lawns, trees and other ornamental plants. Although often underestimated, they are important components of NBS due to their number, size, habitat heterogeneity and habitat continuity. It is open to wide-range communities.

Different variants existing

In terms of green infrastructure there is no common categorization.

A possible division can be: urban, rural or garden, and lawn cemetery. This is primarily based on cultural practices around death and it changes over time, however it can be used in terms of NBS due to their different amount of vegetation.

- Urban cemetery is located in the interior a city, with low or moderate vegetation. They have limited size and cannot easily expand due to adjacent building development.
- Rural or garden cemetery uses landscaping in a park-like setting. They are not necessarily outside of city.
- Lawn cemetery comprises number of graves in a lawn setting with trees and gardens on the perimeter.

Similarly to urban parks, they can provide some active (walking, socializing) or passive (relaxing, sitting on benches, thinking and reflecting) recreational activities.

Urban cemetery: Saint Vincent Cemetery, Paris, France
http://www.hberlioz.com/Paris/BPSaint_Vincent.html

Garden cemetery: Stockholm, Sweden
© Peter Forsberg

Lawn cemetery: Burnley, UK
http://www.stevensonmemorials.co.uk/cemeteries/burnley-cemetery/

I.2 Urban challenges and sub-challenges related + impacts		
Urban cemetery has only a limited number of benefits (in terms of climate, public health, biodiversity and air quality) compared to the rural (garden) or lawn cemetery.		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate adaptation > 01-2 Climate mitigation 02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 07| Public health and well-being > 07-2 Acoustics > 07-2 Quality of life > 07-3 Health 08| Environmental justice and social cohesion > 08-1 Environmental justice > 08-2 Social cohesion	- carbon sequestration - reducing the temperature and regulating the microclimate at neighbourhood and object scale (localized warming) by evapotranspiration and shading - intercepting of stormwater and reducing run-off - providing habitats and food for biodiversity, promoting species diversity - connecting green spaces - acting on sound propagation and perception - noise shielding - increasing physical activity, well-being, and improving/supporting health, moderating stress - education, environmental education - encouraging social interaction, social cohesion
Co-benefits and challenges foreseen	03| Air quality 05| Soil management > 05-1 Soil management 09| Urban planning and governance > 09-1 Urban planning and form 11| Green economy > 11-3 Direct economic value of NBS	- absorbing particles and pollutants - reducing the erosion caused by water run-off, wind speed (losing soil matter), Increase in soil organic matter - increasing the amount of green open space for residents, increasing cultural richness and diversity in urban areas - certain cemeteries (which have cultural and/or natural values) attract tourists - economic benefits: e.g. job opportunities
Possible negative effects	07| Public health and well-being 10| People security	- in some cases: presence of undesired insects - in some cases: producing allergens and contributing to air pollution through the emission of biogenic volatile organic compounds (BVOC) - presence of undesired behaviour

Open air theme lecture for university students at the New Cemetery, Belgrade
http://www.significantcemeteries.org

Free guided tour at the New Cemetery, Belgrade
http://www.significantcemeteries.org

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	District/Neighbourhood scale
Impacted scales	- Object, District/Neighbourhood - City: some impacts take a wider area than the one where the NBS is implemented, e.g. climate of the whole city, well-being of inhabitants, social interaction
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Usually 1-5 years – it depends on the growth of plants and the establishment of amenities. Considering the growth of trees, it could be longer: 10-15 years. Some of its benefits (e.g. significant air quality change, health benefits) will take longer than 5 years to be fully realised.
Life time	More than 10 years – it depends on species, control over and responsible management of species and amenities, as well as resource depletion coming from human activities
Sustainability and life cycle	Cemeteries are active in the sustainable use of biodiversity Professional selection and use of native plants in cemeteries could provide environmental, social, and ecological options for urban brownfield redevelopment into green areas (Smetana and Crittenden, 2014). In several cases cemeteries maintain collections on useful plants of actual or potential value for food, agriculture, forestry, horticulture, ecological purposes (such as habitat management, restoration and reintroduction, land reclamation, soil improvement and stabilisation), amenity (display, tourism, recreation) (Wise, 2000). The general life cycle is long in case of correct maintenance, but it depends on the plants. Some well-managed tree species are maintained more than 100 years. However, some plants are replaced annually, their life cycle is expanded only to the vegetation period of a certain year.
Management aspects (kind of interventions + intensity)	Considering all interventions: weekly intervention (current tasks, highly dependent on current weather and season/month) Maintenance of the areas: - landscaping, mowing, trimming around gravesites, flower and tree planting, grooming, pesticide and herbicide applications, weeding, hoe work, irrigation, raising of saplings, processing fallen and dehydrated trees, pruning, cut branches, removing trees and shrubs, removing leaf litter, suppressing invasive plants, cleaning graves - establishment, maintenance or removal of benches, drinking fountains, etc.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	Relies on partnerships and communication between: owners, co-owners, national and local government, managers
Technical stakeholders & networks	Relies on partnerships and communication between (some of them): urban planners, designers, landscape architects, ecologists, local green spaces managers, funeral company, churches, conservation offices, nonprofit organizations, horticulturists and gardeners
Social aspects	- education, environmental education (school group tours, classes and seminars) - scientific research opportunities - awareness campaigns for public are required to draw attention to the important role of cemeteries in green infrastructures

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- attendance periodicity, visitor density - knowledge of local climate conditions - selection of plants adapted to the local climate and to the size of the cemetery - spatial arrangement of trees - select the most suitable support system (plants, woods, amenities) - use of natural processes (Chan et al., 2018) - the knowledge of recreation management (Chan et al., 2018) - the monitoring of cemetery conditions (Chan et al., 2018)
Materials involved	Wide range of materials due to the wide range of vegetation and amenities. In terms of impact, the vegetation, the pavement materials, the materials of the built objects, and the decorative features have the largest significance, which is very widespread.

II.5 Legal aspects related

They rely on national/municipal laws, e.g. urban structure plan, urban building regulations, urban development laws, concepts, strategies, land use planning regulation, park master plan, regulation on the protection of (local) natural values.
Many countries have developed national and local legislations on cemeteries, funerals, funerary public services.

II.6 Funding Economical aspects	
Range of cost	It highly depends on its size, plants, number of graves, and several local contexts. Some examples: *- Cemetery in Altach, Austria (Fahmy, 2011):* Construction: 2,289,000 EUR (total site area 8,415 m²) Maintenance: 84,000 EUR/year *- A cemetery in Virginia (http://www.amaacemetery.org/projects/):* Operation and maintenance: $6000/year
Origin of the funds (public, private, public-private, other)	Public-private partnerships The origin of the funds can be (some of them): national and local government funding, multi-agency public sector funding (range of government departments and agencies), marketing income, donations from private individuals and corporations, burial and grave fees and charges, national/local historical commissions, nonprofit organizations, conservancies, private foundations, community foundations, company-based foundations

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Some of them can be available in cemeteries:
- environmental friendly solutions: hedge and planted fences, vegetated pergolas, flower beds and fields, lawn, water bodies, fountains, green roofs, climber green walls, living walls systems, build or attached planter systems, permeable pavement, irrigation systems
- conventional solutions: several types of pavement





Unique green cemetery in Varazdin, Croatia. It is part of the Assotiation of significant Cemeteries in Europa (ASCE) and part of the cultural heritage of Croatia.
© Czékus Géza

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- overall character of the city - role in the settlement structure - the nature of the surrounding environment - location, accessibility, connection to the neighbourhoods (distance, road access, trails, sidewalks) - transport links, surrounding traffic intensity - land use functions, cemetery use - total size of the area - selection of plants adapted to the local climate and to the size of the cemetery - proper amenities - keeping competitive weeds out of the cemetery - avoid overuse (vehicles, dogs, littering, vandalism, pickpocket) - use of natural processes (Chan et al., 2018) - ecosystem services (recreation, environmental education, etc.)
Limiting factors	- few authorities have separate cemetery strategies (CABE, 2007) - the failure of higher levels of management within parks or leisure departments to appreciate that “cemeteries are special environments”, which requires much more sensitive and site-specific management and maintenance regimes (CABE, 2007) - absence of proper management information and appreciation of cultural value, which results in low levels of funding (CABE, 2007) - research focusing on cemeteries as urban public green spaces is limited (Nordh and Evensen, 2018) - problems deriving from excessive use of the public, e.g. vehicles, dogs, littering, vandalism, pickpocket. It may cause resource depletion and user conflicts (Chan et al., 2018) - a lack of creativity, a low prioritization, insufficient research support, budgetary constraints (Chan et al., 2018). - challenges associated with lack of expertise in general and participatory management of cemetery maintenance - the complexity in planning and implementing cemeteries, for example, differing property ownership and competition demands, neglecting multi-functionality - inadequate communication and focus on ecosystem disservices - the complex synergies between NBS, governance and community engagement processes at an operational and financial level (Raymond et al., 2017)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Urban brownfield land, empty open space, concrete pavement, lawn
Close NBS	- large urban public parks, public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), botanical gardens, heritage gardens, pocket gardens, private gardens - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems - composting

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- Buchholz, S., Blick, T., Hannig, K., et al. (2016): Biological richness of a large urban cemetery in Berlin. Results of a multi-taxon approach. Biodiversity Data Journal, 4: e7057. Doi: 10.3897/BDJ.4.e7057
- Bull, G. (ed): Green Infrastructure. An integrated approach to land use. Landscape Institute, London, UK
- Cvejic, R., Eler, K., Pintar, M., et al. (2015): A typology of urban green spaces, ecosystem provisioning services and demands. Report of EU FP7 (ENV.2013.6.2-5-603567) GREEN SURGE project (2013-2017)

IV.2 Sources used in this factsheet

- CABE (2007): Cemeteries, churchyards and burial grounds. Commission for Architecture and the Built Environment, London, UK.
- Chan, C-S., Si, F.H., Marafa, L.M. (2018): Indicator development for sustainable urban park management in Hong Kong. Urban Forestry & Urban Greening 31, 1–14
- Fahmy, S. (2011): Islamic Cemetery Altach, Austria. 2013 On Site Review Report. https://archnet.org/system/publications/contents/8748/original/DTP101247.pdf?1391603049
- Nordh, H., Evensen, K.H. (2018): Qualities and functions ascribed to urban cemeteries across the capital cities of Scandinavia. Urban Forestry & Greening. Doi: 10.1016/j.ufug.2018.01.026
- Raymond, C.M., Berry, P., Breil, M., et al. (2017): An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom
- Smetana, S., Crittenden, J.C. (2014): Sustainable plants in urban parks: A life cycle analysis of traditional and alternative lawns in Georgia, USA. Landscape and Urban Planning 122, 140–151
- Virginia cemetery: http://www.amaacemetery.org/projects/
- Wyse Jackson, P.S., Sutherland, L.A. (2000): International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International, U.K.

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Heritage gardens are long-appreciated historic gardens with outstanding aesthetic or scientific values from the past, or they can also be a kind of private gardens that represent all societies at all times, with both tangible and intangible factors (Gao and Dietze-Schirdewahn, 2017).

Two variants exist (according to Gao and Dietze-Schirdewahn, 2017):

1. Historic gardens:
- According to the Florence Charter: 'is an architectural and horticultural composition of interest to the public from the historical or artistic point of view' and a monument that 'must be preserved in accordance with the spirit of the Venice Charter' (ICOMOS, 1982). This means that the focus of garden conservation is to preserve the physical fabric and cultural message of gardens of high historical or artistic value.
- Historic gardens have aesthetic, historic, scientific, social or spiritual values that represent a public and professional interest in places, regardless of ownership.
- They can be on the World Heritage List and various national and regional lists of cultural heritage.
- In most cases they are open to public (Gao and Dietze-Schirdewahn, 2017)

In the early 21st century we should also include more 'ordinary' gardens into garden heritage conservation (Gao and Dietze-Schirdewahn, 2017).

2. Private domestic ('ordinary') gardens:
- They represent the life of broader societies in all periods as well as the related intangible factors such as skills and craftsmanship.
- They are not only the carrier of cultural heritage but also private property. They are places for living and thus change more often than historic gardens according to their users' demands.
- They may have a long history, an aesthetic design, a good collection of plants, a unique setting; however, family influence, social networks, living environment and activities such as gardening, experimenting, harvesting all contribute to the creation of unique private gardens (Gao and Dietze-Schirdewahn, 2017).
- In most cases they are not open to public, but on special days, or by appointment they open their doors.

Large historic garden of Wenckheim Castle, Szabadkigyos, Hungary
http://sulinet.hu

Large historic garden of Károlyi Castle, Füzérradvány, Hungary
http://www.forsterkozpont.hu

Heritage garden, Wightwick Manor, Wolverhampton, UK
© Andrew Butler / NTPL

Heritage garden, Bowthorpe, Norfolk, UK
http://uk.iofc.org

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate adaptation > 01-2 Climate mitigation 02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development 07| Public health and well-being > 07-2 Acoustics > 07-2 Quality of life > 07-3 Health 08| Environmental justice and social cohesion > 08-1 Environmental justice > 08-2 Social cohesion	- carbon sequestration - reducing the temperature and regulating the microclimate at neighbourhood or object scale (localized warming) by evapotranspiration and shading - intercepting of stormwater and reducing run-off - supporting a wide range of plants (native plants and special plant collections), preserving and applying plant diversity, plant conservation plan, long-term maintenance - historic gardens: noise shielding - providing leisure and recreation facilities (relaxing, casual strolls) - aesthetic value - increasing physical activity, well-being, and improving/supporting health, moderating stress - cognitive development, improvement of opportunities for exploration by children (reconnect children with nature) - education, environmental education - facilitating social interaction and community attachment, interaction among neighbours, promoting social cohesion
Co-benefits and challenges foreseen	03| Air quality 05| Soil management > 05-1 Soil management 09| Urban planning and governance > 09-1 Urban planning and form 11| Green economy > 11-3 Direct economic value of NBS	- absorbing particles and pollutants - reducing the erosion caused by water run-off, wind speed (losing soil matter), Increase in soil organic matter - increasing the amount of green open space for residents, increasing cultural richness and diversity in urban areas - certain heritage garden (primarily the historic gardens) attract tourists, and in several cases are among their motivations to visit certain regions/cities - in some cases: delivering multiple economic benefits, e.g. job opportunities, increasing the value of close properties, increasing tax revenues
Possible negative effects	07| Public Health and well-being	- in some cases: presence of undesired insects - in some cases: producing allergens and contributing to air pollution through the emission of biogenic volatile organic compounds (BVOC)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	- Object: small private domestic gardens - District/Neighbourhood: historic gardens and large private domestic gardens
Impacted scales	- Object, District/Neighbourhood - City: large historic gardens only; some impacts take a wider area than the one where the NBS is implemented, e.g. climate of the whole city, well-being of inhabitants, social interaction
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Usually 1-5 years – it depends on the establishment and development of plants and amenities. Considering the growth of trees in the case of historical gardens, it could be longer: 10-15 years. Some of its benefits (e.g. significant air quality change, social habit change, health benefits) will take longer than 5 years to be fully realised
Life time	More than 10 years – it depends on species, control over and responsible management of species and amenities, motivation of the involved people, as well as resource depletion coming from human activities
Sustainability and life cycle	Heritage gardens are active in the sustainable use of biodiversity. Professional selection and use of native plants in heritage gardens could provide environmental, social, and ecological options for urban brownfield redevelopment into green areas (Smetana and Crittenden, 2014). In several cases heritage gardens maintain extensive collections of useful plants with actual or potential value for food, agriculture, forestry, horticulture, ecological purposes (habitat management, restoration and reintroduction, land reclamation, soil improvement and stabilisation), amenity (display, tourism, recreation), essential oils, fuel, medicinal plants, forage and many other purposes (Wise, 2000). The general life cycle is long in case of correct maintenance, but it depends on the chosen plants. Some well-managed tree species are maintained more than 100 years. However, some plants are replaced annually, their life cycle is expanded only to the vegetation period of a certain year.
Management aspects (kind of interventions + intensity)	Considering all interventions: weekly intervention (current tasks, highly dependent on current weather and season/month) Maintenance of areas: - landscaping, mowing, flower and tree planting, grooming, pesticide and herbicide applications, weeding, hoe work, irrigation, raising of saplings, pruning, cut branches, removing trees and shrubs, processing fallen and dehydrated trees, removing leaf litter, suppressing invasive plants, wild protection - establishment, maintenance or removal of benches, fountains, drinking fountains, and other departments - in particular case, maintenance of automatic irrigation systems

Gardeners at work at Osborne house, East Cowes, UK
http://www.english-heritage.org.uk

Gardener at work at a heritage garden, Durham, UK
© Chris Watt / Telegraph

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	Relies on partnerships and communication between (some of them): - Historic gardens: owners, co-owners, national and local government, culture heritage protection agencies, managers - Private domestic gardens: private owners, co-owners (and their family), community groups, local government, managers
Technical stakeholders & networks	Relies on partnerships and communication between (some of them): - Historic gardens: urban planners, designers, landscape architects, ecologists, local green spaces managers, culture heritage protection agencies, nonprofit organizations - Private domestic gardens: private owners, co-owners and their family, community groups, horticulturists and gardeners, local green spaces managers
Social aspects	- private owners, co-owners, their family, as well as neighborhoods: gardening, experimenting, creating, and gathering socially → community can be strengthened due to the collective work - historic gardens and private gardens: education, environmental education (school group tours, classes and seminars) - scientific research opportunities - periodic programmes to raise awareness, promote public understanding of biodiversity, its importance and loss

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- the nature of the surrounding environment - accessibility, connection to the neighbourhoods (distance, road access, trails, sidewalks) - transport links, surrounding traffic intensity - land use needs, garden use - attendance periodicity, visitor density - local climate conditions - selection of plants - select the most suitable support system (plants, woods, amenities) - use of natural processes (Chan et al., 2018) - the knowledge of recreation management (Chan et al., 2018)
Materials involved	Wide range of materials due to the wide range of vegetation and amenities. In terms of impact, the vegetation, the pavement materials, the materials of the garden buildings, and the decorative features have the largest significance, which is very widespread.

II.5 Legal aspects related
- Historic gardens: They rely on national/municipal laws, e.g. urban structure plan, urban building regulations, urban development laws, concepts, strategies, park master plan, land use planning regulation. Many countries have developed national legislation and/or national strategies and action plans on cultural heritage protection, as well as biodiversity/nature conservation and environmental protection. - Private heritage gardens: in particular case, necessity to find an agreement with all the co-owner of a building

II.6 Funding Economical aspects	
Range of cost	It highly depends on its size, plants, amenities and several local contexts. *Heritage garden, Bowthorpe, Norfolk, UK (http://uk.iofc.org):* - rented the land from Norwich City Council for £1 a year - funding for insurance, new plants and tools comes from membership fees, 40 members, yearly fee of £6 or £12 + donations of plants from well-wishers
Origin of the funds (public, private, public-private, other)	Historic gardens: public or public-private partnerships - the origin of the funds can be (some of them): national and local government funding, multi-agency public sector funding (range of government departments and agencies), marketing income, entrance ticket, revenue-raising public entertainment facilities (music, theatre, etc.), donations from private individuals and corporations, national/local historical commissions, nonprofit organizations, conservancies, private foundations, community foundations, company-based foundations Private heritage gardens: mainly private fund - the origin of the funds can be (some of them): donations from private individuals (including local residents) and corporations, community groups set up by local residents, donations from well-wishers

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Some of them can be available in heritage gardens: - environmental friendly solutions: hedge and planted fences, vegetated pergolas, flower beds and fields, lawn, water bodies, fountains, green roofs, climber green walls, living walls systems, build or attached planter systems, permeable pavement, irrigation systems - conventional solutions: several types of pavement

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- the nature of the surrounding environment - location, accessibility, connection to the neighbourhoods (distance, road access, trails, sidewalks) - transport links, surrounding traffic intensity - total size of the area - land use needs, garden use - attendance periodicity, visitor density - knowledge of local climate conditions - selection of plants - in some cases: adequate labelling of the plants - proper amenities - keeping competitive weeds out of the garden - sustainable irrigation system - select the most suitable support system (plants, woods, amenities) - avoid overuse (vehicles, littering, carving on trees, vandalism, pickpocket) - use of natural processes (Chan et al., 2018) - recreation management (Chan et al., 2018) - the continuous monitoring of garden conditions (Chan et al., 2018) - widespread ecosystem services (leisure, sport, recreation, environmental education, etc.) for everyone - appropriate conditions for socializing - acceptance of the locals, popular pastime

Limiting factors	- there is a gap between professionals' and garden owners' opinion in evaluating and treating garden heritage (Gao and Dietze-Schirdewahn, 2017). - historical gardens: problems deriving from excessive use of the public, e.g. littering, carving on trees, vandalism, pickpocket. It may cause resource depletion and user conflicts (Chan et al., 2018) - maintenance and restoration is expensive - low prioritization for resource allocation, an ineffective public sector, budgetary constraints - challenges associated with lack of expertise in general and participatory management of heritage garden maintenance - the complexity in planning and implementing historical gardens, for example, differing property ownership and competition demands, neglecting multi-functionality - inadequate communication and focus on ecosystem disservices - the complex synergies between NBS, governance and community engagement processes at an operational and financial level (Raymond et al., 2017)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Urban brownfield land, empty open space, concrete pavement, lawn
Close NBS	- large urban public parks, public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), green cemeteries, botanical gardens, pocket gardens, private gardens, urban fam, urban vineyard, vegetable gardens, urban orchards - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems - composting, mulching

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- Bull, G. (ed): Green Infrastructure. An integrated approach to land use. Landscape Institute, London, UK
- Cvejic, R., Eler, K., Pintar, M., et al. (2015): A typology of urban green spaces, ecosystem provisioning services and demands. Report of EU FP7 (ENV.2013.6.2-5-603567) GREEN SURGE project (2013-2017)

IV.2 Sources used in this factsheet

- Chan, C-S., Si, F.H., Marafa, L.M. (2018): Indicator development for sustainable urban park management in Hong Kong. Urban Forestry & Urban Greening 31, 1–14
- Gao, L., Dietze-Schirdewahn, A. (2017): Garden culture as heritage: A pilot study of garden culture conservation based on Norwegian examples. Urban Forestry & Urban Greening. Doi: 10.1016/j.ufug.2017.03.010
- Heritage Garden Bowthorpe: http://uk.iofc.org/bowthorpe-heritage-gardens-spiritual-heart-community
- ICOMOS (1982): Historic Gardens. The Florence Charter – 1982. https://www.icomos.org/en/what-we-do/focus/179-articles-en-francais/ressources/charters-and-standards/158-the-florence-charter
- Raymond, C.M., Berry, P., Breil, M., et al. (2017): An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom
- Smetana, S., Crittenden, J.C. (2014): Sustainable plants in urban parks: A life cycle analysis of traditional and alternative lawns in Georgia, USA. Landscape and Urban Planning 122, 140–151
- Thake, A. (2009): Heritage garden restoration and maintenance. International Specialised Skills Institute, Melbourne, Australia
- Wyse Jackson, P.S., Sutherland, L.A. (2000): International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International, U.K.

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> LARGE URBAN PUBLIC PARK

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Large urban public parks refer to large green areas within a city with a variety of active and passive recreational facilities that meet the recreational and social needs of the residents and of visitors to the city. They are open to wide-range communities. In the optimal case they can be reached in 10-15 walking minutes by each resident.

Different variants existing

Although they can be different due to their size and location (inner city, suburbs), there are no common variants in terms of NBS. Large urban parks serve all the city or part of city.
However, they can be divided into several active and passive recreational areas.

- Passive recreation often involves relatively quiet and low intensity activities and might require amenities like paths or benches. It emphasizes the open-space aspect of a park and allows for the preservation of natural habitat.
- Active recreation often involves cooperative or team activity, it might be somewhat noisy and might require facilities like playgrounds, ball fields or swimming pools.

Some examples:

- Passive recreation areas: natural forest reserves, grassy areas, flower beds, water bodies, fountains, sunbathing lawns, rustic picnic areas, etc.
- Active recreation areas: sports fields and courts; walking, running, cycling and fitness trails or paths; playgrounds; water bodies; etc.

Active recreation area – playground in Városliget, Budapest
http://www.budapestnet.hu/

Passive recreation area – sunbathing hill in Városliget, Budapest
http://www.mut.hu/

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate adaptation > 01-2 Climate mitigation 02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 07| Public health and well-being > 07-1 Acoustics > 07-2 Quality of life > 07-3 Health 08| Environmental justice and social cohesion > 08-1 Environmental justice > 08-2 Social cohesion	- carbon sequestration - reducing the temperature and regulating the microclimate at neighbourhood and object scale (localized warming) by evapotranspiration and shading - intercepting of stormwater and reducing run-off - providing habitats and food for biodiversity, promoting species diversity - habitat for insects and birds - connecting green spaces - acting on sound propagation and perception - increasing physical activity, well-being, and improving/supporting health, moderating stress - providing leisure, sport and recreation facilities - aesthetic value - cognitive development, improvement of opportunities for exploration by children (reconnect children with nature) - education, environmental education - facilitating social interaction and community attachment, interaction among neighbours, promoting social cohesion
Co-benefits and challenges foreseen	03| Air quality 05| Soil management > 05-1 Soil management 09| Urban planning and governance > 09-1 Urban planning and form 11| Green economy > 11-3 Direct economic value of NBS	- absorbing particles and pollutants - reducing the erosion caused by water run-off, wind speed (losing soil matter), increase in soil organic matter - increasing the amount of green open space for residents, increasing cultural richness and diversity in urban areas - attractive to tourists (are among their motivations to visit certain regions/cities) - delivering multiple economic benefits, e.g. job opportunities, increasing the value of close properties, increasing tax revenues
Possible negative effects	07| Public health and well-being 10| People security	- in some cases: presence of undesired insects - in some cases: producing allergens and contributing to air pollution through the emission of biogenic volatile organic compounds (BVOC) - presence of undesired behaviour

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	District/Neighbourhood scale (In Hungary: at least 1 ha, with even the smallest side is larger than 80 m. The most effective for supporting its use and benefits is at least a 3-4 ha coherent area).
Impacted scales	- Object, District/Neighbourhood - City: some impacts take a wider area than the one where the NBS is implemented, e.g. climate of the whole city, well-being of inhabitants, social interaction
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Usually 1-5 years – it depends on the growth of plants and the establishment of amenities. Considering the growth of trees, it could be longer: 10-15 years. Some of its benefits (e.g. significant air quality change, social habit change, health benefits) will take longer than 5 years to be fully realised
Life time	More than 10 years – it depends on species, control over and responsible management of species and amenities, as well as resource depletion coming from human activities
Sustainability and life cycle	Urban parks are active in the sustainable use of biodiversity. Professional selection and use of native plants in urban parks could provide environmental, social, and ecological options for urban brownfield redevelopment into green areas. Native plants adapted to the local climate and soil conditions require less maintenance and therefore less money (water, fertilizers, pesticides, mowing, etc.), help reduce air pollution (less mowing) and withstand regional climate extremes, promote regional biodiversity and provide natural habitats for wildlife (Smetana and Crittenden, 2014). In several cases urban parks maintain collections of useful plants with actual or potential value for food, agriculture, forestry, horticulture, ecological purposes (such as habitat management, restoration and reintroduction, land reclamation, soil improvement and stabilisation), amenity (display, tourism, recreation) (Wise, 2000). The general life cycle is long in case of correct maintenance, but it depends on the plants. Some well-managed tree species are maintained more than 100 years. However, some plants are replaced annually, their life cycle is expanded only to the vegetation period of a certain year.
Management aspects (kind of interventions + intensity)	Considering all interventions: almost daily intervention (current tasks, highly dependent on current weather and season/month) Maintenance of the active and passive recreation areas: - landscaping, mowing, flower and tree planting, grooming, pesticide and herbicide applications, weeding, hoe work, irrigation, raising of saplings, pruning, cutting branches, removing trees and shrubs, processing fallen and dehydrated trees, removing leaf litter, suppressing invasive plants - establishment, maintenance or removal of playgrounds, benches, sport courts, fountains, drinking fountains, etc. - maintenance of automatic irrigation systems

Maintenance works (planting, irrigation, mowing) in large urban public parks in Budapest, Hungary
http://www.fokert.hu

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	Relies on partnerships and communication between: owners, co-owners, national and local government, managers
Technical stakeholders & networks	Relies on partnerships and communication between (some of them): urban planners, designers, landscape architects, ecologists, local green spaces managers, nonprofit organizations, horticulturists and gardeners
Social aspects	- implementation, management and maintenance of urban parks: the residents do not only use the green spaces but can be active partners in them. It is important to increase their involvement in these activities, which require awareness campaigns, trainings. - periodic programmes to promote public understanding of biodiversity, its importance and loss - offer learning opportunities through educational outreach (classes, seminars, school group tours) - scientific research opportunities

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- overall character of the city - the nature of the surrounding environment - accessibility, connection to the neighbourhoods (distance, road access, trails, sidewalks) - transport links, surrounding traffic intensity - land use functions, park use - land use needs, park use - attendance periodicity, visitor density - area requirements for the number of visitors (satisfying the needs of the population) - local climate conditions - selection of plants adapted to the local climate and to the size of the park - select the most suitable support system (plants, woods, amenities) - use of natural processes (Chan et al., 2018) - recreation management (Chan et al., 2018)
Materials involved	Wide range of materials due to the wide range of passive and active recreation tools (see above), as well as vegetation. In terms of impact, the vegetation, the pavement materials, the materials of the built objects, and the decorative features have the largest significance, which is very widespread.

II.5 Legal aspects related

The legal aspects can differ depending on the individual amenities of the park.
They rely on national/municipal laws, e.g. urban structure plan, urban building regulations, urban development laws, concepts, strategies, land use planning regulation, park master plan, regulation on the protection of (local) natural values.

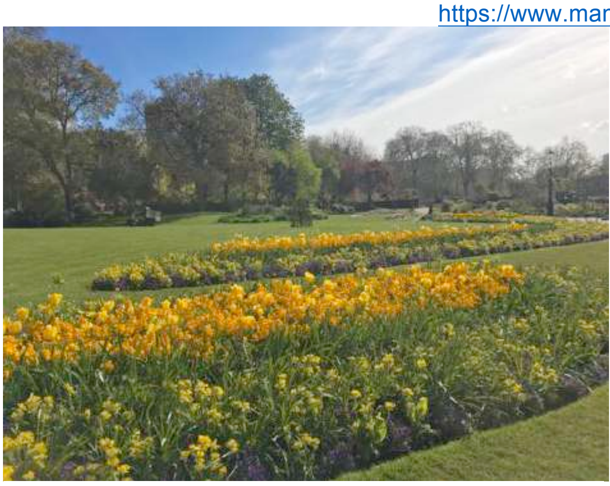
II.6 Funding Economical aspects	
Range of cost	Creation: *According to a Report for the City of Minneapolis (DuMoulin et al., 2008):* - Two principal costs exist: acquiring the land and developing the facility itself (including design and construction costs). Cost estimates for park creation take into account many factors: the size and shape of the park, existing public ownership of the site or potential exchange sites, existing site conditions, development features, complexity of design, and construction of facilities like playground. - Costs ranges from $481,333 with no land acquisition and few park features, to $9,981,250 per acre including a wide range of park features and performance spaces. Operation and maintenance: *According to the Report for the City of Minneapolis* and *Tempesta (2015):* - The maintenance cost includes employee payroll and landscaping costs. - This cost can vary widely depending on the specific characteristics of a park, its design and use, the park management structure and several local contexts. *According to the Report for the City of Minneapolis:* - Annual operating costs range from $229,000 to $884,00 per acre *According to Tempesta (2015):* - Veneto Region, Italy: 0.39 to 2.73 EUR/year/m^2 (constant price 2012); 10.08 EUR/inhabitant/year - 15 UK parks: 0.28 to 1.34 EUR/year/m^2, 10.61 to 44.12 EUR/inhabitant/year (constant price 2002) Creation, operation and maintenance:

	According to the Report for the City of Minneapolis: - A more highly programmed, designed and maintained park in Minneapolis may cost $6,000,000 to $8,000,000 per acre to develop and $500,000 to $700,000 to operate, while a park with fewer features and programming may cost $1,000,000 to $3,000,000 to develop and $200,000 to $400,000 to operate. These estimates do not include land acquisition costs.
Origin of the funds (public, private, public-private, other)	Public or Public-private partnerships The origin of the funds can be (some of them): national and local government funding, multi-agency public sector funding (range of government departments and agencies), marketing income, donations from private individuals and corporations, nonprofit organizations, conservancies, private foundations, community foundations, company-based foundations

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Some of them can be available in large urban parks:
- environmental friendly solutions: hedge and planted fences, vegetated pergolas, flower beds and fields, lawn, water bodies, fountains, green roofs, climber green walls, living walls systems, build or attached planter systems, permeable pavement, irrigation systems
- conventional solutions: several types of pavement

Vegetated pergola in Hyde Park, London
https://www.mandarinoriental.com



Flower field in Hyde Park, London
https://jannaschreier.com

Living wall at Finsbury Circus, an urban park in the City of London
https://www.bloknmesh.com

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- overall character of the city - role in the settlement structure - the nature of the surrounding environment - location, accessibility, connection to the neighbourhoods (distance, road access, trails, sidewalks) - transport links, surrounding traffic intensity - land use needs, park use - attendance periodicity, visitor density - area requirements for the number of visitors (satisfying the needs of the population) - proper amenities - keeping competitive weeds out of the park - sustainable irrigation system - avoid overuse (vehicles, dogs, littering, vandalism, pickpocket) - recreation management (Chan et al., 2018) - the monitoring of park conditions (Chan et al., 2018) - widespread ecosystem services (leisure, sport, recreation, environmental education, etc.) for everyone - appropriate conditions for socializing - acceptance of the locals, popular pastime
Limiting factors	- problems deriving from excessive use of the public, e.g. vehicles, dogs, littering, vandalism, pickpocket. It causes park resource depletion and user conflicts in park spaces (Chan et al., 2018) - dynamic nature of park visits, a lack of creativity, a low prioritization, and an ineffective public sector, insufficient research support, budgetary constraints (Chan et al., 2018) - challenges associated with lack of expertise in general and participatory management of urban park maintenance - the complexity in planning and implementing urban parks, for example, differing property ownership and competition demands, neglecting multi-functionality - inadequate communication and focus on ecosystem disservices - the complex synergies between NBS, governance and community engagement processes at an operational and financial level (Raymond et al., 2017)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Urban brownfield land, empty open space, concrete pavement, lawn
Close NBS	- public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), green cemeteries, botanical gardens, heritage gardens, pocket gardens, private gardens - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems - composting

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- Breuste, J., Rahimi, A. (2015): Many public urban parks, but who profits from them? The example of Tabriz, Iran. Ecological Processes 4:6
- Bull, G. (ed): Green Infrastructure. An integrated approach to land use. Landscape Institute, London, UK
- Chiesura, A. (2004): The role of urban parks for the sustainable city. Landscape and Urban Planning, 68, 129–138
- Cvejic, R., Eler, K., Pintar, M., et al. (2015): A typology of urban green spaces, ecosystem provisioning services and demands. Report of EU FP7 (ENV.2013.6.2-5-603567) GREEN SURGE project (2013-2017)
- Issue Brief, National Recreation and Park Association (NRPA), Ashburn, USA
- Larson, L.R., Jennings, V., Cloutier, S.A. (2016): Public Parks and Wellbeing in Urban Areas of the United States. PLoS ONE 11, e0153211. Doi:10.1371/journal.pone.0153211
- Morley, D. (2017): Planning for equity in parks with green infrastructure. Great urban parks campaign Briefing Papers 2, American Planning Association, Chicago, USA

IV.2 Sources used in this factsheet

- Chan, C-S., Si, F.H., Marafa, L.M. (2018): Indicator development for sustainable urban park management in Hong Kong. Urban Forestry & Urban Greening 31, 1–14
- DuMoulin, A., Welle, B., Harnik, P., et al. (2008): Downtown Parks: Funding Methods, Management Structures, and Costs. A Report for the City of Minneapolis. http://cloud.tpl.org/pubs/ccpe-DowntownParkFinance-inMN.pdf
- Raymond, C.M., Berry, P., Breil, M., et al. (2017): An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom
- Smetana, S., Crittenden, J.C. (2014): Sustainable plants in urban parks: A life cycle analysis of traditional and alternative lawns in Georgia, USA. Landscape and Urban Planning 122, 140–151
- Tempesta, T (2015): Benefits and costs of urban parks: a review. Aestimum 67, 127–143
- Wyse Jackson, P.S., Sutherland, L.A. (2000): International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International, U.K.

V/ Author(s)

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	A lawn is an area land covered with soil, planted with grasses and other durable plants such as clover, which are maintained at a short height. Common characteristics of a lawn are that it is composed only of grass species, it is subject to weed and pest control, it is subject to practices aimed at maintaining its green colour (e.g., watering), and it is regularly mowed to ensure an acceptable length, although these characteristics are not binding as a definition. Lawns are used around houses, apartments, commercial buildings and offices, and they can also be found in urban parks. Lawns have an important role in daily life of inhabitants, through their aesthetic and recreational value. Proper lawn maintenance plays a crucial part in any landscape design. [1],[2]

Different variants existing

Though lawns may contain many other types of plants (e.g. mono- and dicot herbaceous plants), lawns might be grouped based on the types of dominant, stand-forming grasses. There are dozens of grass species that are potentially usable for lawn making, but the three basic categories below can be distinguished:

- **Cool season grasses:** Cool season grasses grow in climates that have relatively mild/cool summers, with two periods of rapid growth in the spring and autumn. Cool season grasses do not go dormant, they retain their color well in extreme cold and typically grow very dense. Cool season varieties include bluegrass (*Poa spp.*), fescue species (*Festuca spp.*), and rye grass (*Lolium spp.*).
- **Warm season grasses:** Warm season grasses only start growth at higher temperatures (~above 10 ºC), and often go dormant in cooler months. They have one long growth period over the spring and summer. (During the cooler winter months, many cool season grasses are used for overseeding to provide a green lawn all year long.) Many warm season grasses are quite drought tolerant, and can handle very high summer temperatures. Some examples of warm season grasses are zoysiagrass *(Zoysia spp.)* and bermudagrass *(Cynodon spp.)* species.
- **Grass alternatives:** As lawns are sometimes exposed to drought, and need high maintenance efforts, sedge (*Carex spp.*) and some other species can serve as sustainable alternatives to grass species [1],[3].

Comparison of Kentucky bluegrass and Fine-leaved fescue lawn

https://www.extension.umn.edu

Zoysia lawn sample

http://earthscapesunlimitied.webs.com

Bermudagrass lawn

https://www.lawn-care-academy.com

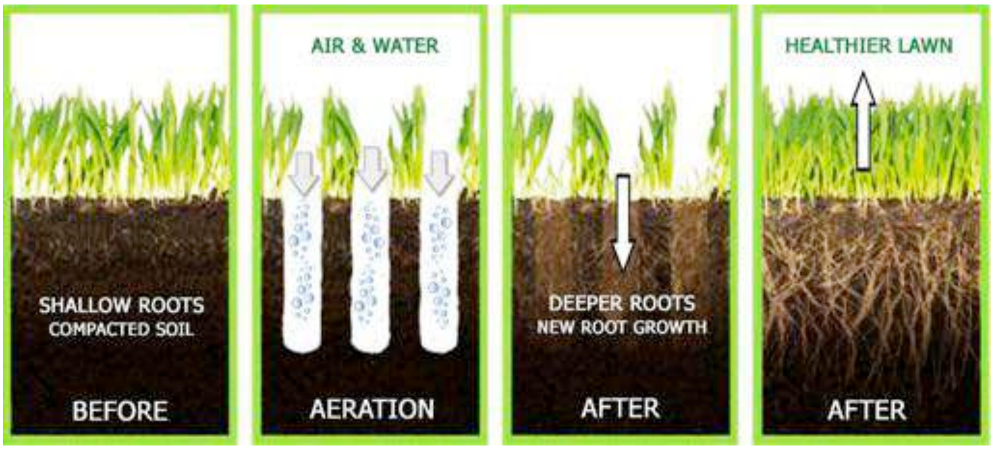
Sedge lawn

https://www.gardeningknowhow.com

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues >01-2 Climate mitigation 02| Urban water management and quality > 02.-2 Urban water management 07| Public health and well-being > 07.-2 Quality of life > 07.-3 Health	- sequestering atmospheric carbon dioxide - limit run-off water - well-maintained lawns have considerable aesthetic value - lawns can motivate people to physical activity → well-being, and improving/supporting health, moderating stress
Co-benefits and challenges foreseen	01| Climate issues >01-1 Climate adaptation 02| Urban water management and quality > 02.-2 Flood management 03| Air quality 04| Biodiversity and Urban Space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 05| Soil management 08| Environmental justice and social cohesion	- reducing the temperature and regulating the microclimate on the object scale (heat stress mitigation) by evapotranspiration - interception of stormwater - air pollution removing - providing habitat for several species, promoting biodiversity - creating connections - Increase in soil organic matter - through providing space for picnics or gathering of many people, they facilitate social interaction and community attachment, interaction among neighbours, promote social cohesion
Possible negative effects	07| Public Health and well-being > 07-3 Health	- in some cases: providing habitat for undesired insect species - in some cases: providing habitat for allergenic species (e.g. ragweed)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Object and neighbourhood scale
Impacted scales	Neighbourhood
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	- 1-2 years - lawns need quite careful maintenance to become and remain effective, through their whole life cycle
Life time	- 5-10 years - overseeding may help to extend life time
Sustainability and life cycle	Perennial plants may provide a sustainable alternative to conventional urban horticultural techniques (e.g. because of a lower irrigation need).
Management aspects (kind of interventions + intensity)	- Possible lawn maintenance activities: mowing, aerating, raking, watering, lawn feeding - Lawn types/species with lower management intensity can be considered more sustainable alternatives  Mechanism and positive effects of lawn aeration https://www.thelawninstitute.org
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	"There is a common positive view of lawns as functional and accessible areas in parks, playgrounds and private gardens. Lawns often have symbolic value and people enjoy them (see, hear, smell etc.), although they may be not permitted to enter or use the lawn area. However, the intensive management practices used on lawns, such as frequent mowing and spraying of herbicides and fertilisers, has raised awareness about their potential negative impact on the urban environment. All previous research on urban biotopes has shown that lawns are strikingly similar in terms of plant species composition and, in their modern expression, are important contributors to the homogenisation of urban landscapes and loss of urban biodiversity" *(Ignatieva, 2011)*. Stakeholders are connected to all main areas of lawn management (economy; social-cultural-historical; planning and design; biodiversity-environmental impact). Therefore, stakeholder involvement is crucial in the whole process of lawn management, and in research programs as well *(Ignatieva et al. 2015).*
Technical stakeholders & networks	Urban planners, landscape architects, ecologists, local green spaces managers, non-profit organizations
Social aspects	Careful lawn maintenance played a role in social relations, several times in history (mainly around private homes), e.g. the well-maintained lawns became a symbol of moral integrity, safety and stability. *(Dickinson 2006)*

II.4 Design / techniques/ strategy

Knowledge and how-know involved	Sustainable lawn care practices: • Set expectations and tolerance levels e.g. sustainable practices start with educating customers about the value of a healthy, durable, good-looking lawn with: a meadow-green color, some broadleaf plants, reasonable mowing height, etc. • Assess the site to plan practices: sun, soil, drainage, traffic & use zones, etc. • Mowing: - Mow higher, mow regularly, and leave the clippings - Mulch mowing builds healthier lawns, saves time and money • Fertilizing for lawn health: - Mulch mowing returns most nutrients needed - Slow-release fertilizers, either from natural organic or nonsoluble synthetic formulations, provide longer, better grass nutrition, and are less toxic to beneficial soil life than soluble "quick-release" synthetics. - etc. • Watering: irrigating for lawn health: deep, slow, less frequent • Integrated pest management: - Correctly identify pests and understand their life cycles - Establish tolerance thresholds: accept some pests/weeds - Monitor to detect and prevent pest problems - etc. ("Natural Lawn Care" guide, [4])
Materials involved	• Equipments: drop spreader, lawn mower, leaf rake, leaf blower, sprinkler, etc. • Materials: seeds, possibly organic lawn fertilizer, water for irrigation

II.5 Legal aspects related

Most of urban lawns are owned by the municipality, therefore mostly the local council's regulations are relevant for them.

II.6 Funding Economical aspects

Range of cost	Costs of lawn mowing and maintenance: $81.70 per visit (1 acre) (range: $66.67 - $96.72) Cost of Fertilizing a Lawn: $107.34 per application (1 acre) (range: $92.49 - $122.18) (U.S. averages, [5])
Origin of the funds (public, private, public-private, other)	Depends on the ownership (as lawns are mainly publicly owned, the source of funds is mainly the municipality budget).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Lawns often form a borderline of other NBS entities, e.g. a stormwater retention pond or a flower field in the images below.

Stormwater retention pond bordered by lawns
https://wildlifedepartment.com

Lawn with flower feld and single trees
https://www.extension.umn.edu

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Fundamentals of eco-friendly lawn care: • Start with good soil • Base fertility programs on soil test results • Use naturally derived soil amendments and fertilizers • Limit nitrogen applications • Leave lawn clippings to decompose back into the soil • Mow at around three inches • Look for power alternatives • Match grass species and types to site conditions, and provide diversity • Set irrigation systems properly and keep in good repair • Try to live with the "weeds." • Use supplemental applications of micronutrients, bio-stimulants, and soil conditioners • Add good-quality compost to lawns • Use corn gluten meal (a byproduct of corn milling) to reduce weed seed growth, especially crabgrass • Consider compost tea (Nick Novick, Ecological Landscape Alliance [6])
Limiting factors	As most types of lawns need careful maintenance, they are relatively highly exposed to changes in environmental factors and circumstances. For example, lawns needing high amount of irrigation might become unsustainable (in economic terms as well) as a result of climate change effects.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Empty open space, concrete pavement
Close NBS	- public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.) - choice of plants, flower fields, green strips, meadows

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Garrett H. (2016): Organic Lawn Care – Growing Grass the Natural Way. University of Texas Press, 168 p.

Owen, M.C., Lanier, J.D. (eds.) (2013): Best Management Practices for Lawn and Landscape Turf. UMass Extension – Center for Agriculture. 120 p.

Tukey P.B. (2007): The Organic Lawn Care Manual: A Natural, Low-Maintenance System for a Beautiful, Safe Lawn. Storey Publishing, 271 p.

IV.2 Sources used in this factsheet

Dickinson G. (2006): The Pleasantville Effect: Nostalgia and the Visual Framing of (White) Suburbia. Western Journal of Communication. 70, 212-233.

Ignatieva M. (2011): Plant Material for Urban Landscapes in the Era of Globalization: Roots, Challenges and Innovative Solutions. In: Richter M., Weiland U. (eds.): Applied Urban Ecology: A Global Framework, 1. Wiley-Blackwell Publishing, Oxford, pp. 139 - 161.

Ignatieva M., Ahrné K., Wissman J., Eriksson T., Tidaker P., Hedblom M., Kätterer T., Marstorp H., Berg P., Eriksson T., Bengtsson J. (2015): Lawn as a cultural and ecological phenomenon: A conceptual framework for transdisciplinary research. Urban Forestry and Urban Greening 14, 383-387.

Internet sources:

[1]: https://en.wikipedia.org/wiki/Lawn

[2]: http://agritech.tnau.ac.in/horticulture/horti_Landscaping_lawn%20making.html

[3]: https://sodsolutions.com/blog/2015/02/23/warm-vs-cool-season-grass/

[4]: http://www.seattle.gov/util/ProIPM

[5]: https://lawn-care.promatcher.com/cost/

[6]: https://www.ecolandscaping.org/04/lawn-care/ecological-lawn-care-2/

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> POCKET GARDEN/PARK

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Small and compact park-like areas or small gardens around and between buildings vegetated by ornamental trees, grass and other types of plants (perennial, annual plants, herbaceous), publicly accessible (Nordh and Østby, 2013; Braquinho et al. 2015). They can be tucked into and scattered throughout the urban fabric as stepping stones for species (Ramirez and Zuria, 2011, Konijnendijk et al., 2013). Because of its size it usually does not provide opportunities for great physical activity, but their functions include small event space, play areas for children, spaces for relaxing, meeting friends and other social activities, taking lunch outdoor and to some extent fill the need for peoples every day contact with nature (Dunett et al. 2002; Cohen et al., 2014; Armano, 2017; Bitterman N. and Simonov E., 2017; Peschardt 2014).

Different variants existing

In general, pocket parks can be considered a subset of urban parks (Jasmani, 2013). Terminology does not sharply separate pocket park and pocket garden concepts, both of which belong to the category of small public urban green spaces (SPUGS) (Nordh et al., 2009; Peschardt et al., 2012). They can be described in various ways depending on their purpose, components, location and function, therefore, we can give their types based on this:

- small green spaces released in dense urban fabric*
- a garden built in the interior of large blocks of houses**
- small front gardens closely linked houses (public green spaces)***
- specifically designed pocket park for special physical activity (pl. skateboard park) (They have limited possibilities for other activities due to their restricted size and special design)

Pocket park* in the densely-built up region of Tel Aviv (Jaffa), Israel (Photo: Ágnes Gulyás)

Pocket garden** built in the courtyard of an old apartment block in Budapest, Hungary http://www.szepkertert.hu/blog/104/egy-belvarosi-berhaz-kertjenek-megujulasa

Pocket garden* built in the middle of a traffic circle in Szeged, Hungary (Photo: Ágnes Gulyás)

Pocket garden*** in front of Greenwood Theatre in London, Great Britain http://helengazeley.typepad.co.uk/gardenwriter/2015/05/joe-swift-zandra-rhodes-greenwood-theatre-pocket-park-london-se1.html

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues 01-2 Climate adaptation 07| Public health and well-being 07-2 Quality of Life 07-3 Health 08| Environmental justice and social cohesion 08-2 Social cohesion	- reducing the temperature and regulate the microclimate at object scale by evapotranspiration and shading - reducing heat stress - increasing well-being, and supporting health, reduce stress and anxiety - aesthetic value - facilitate social interaction and community attachment, interaction among neighbours, promote social cohesion
Co-benefits and challenges foreseen	02| Urban water management and quality 02-1 Urban water management 02-2 Flood management 03| Air quality 03-2 Air quality locally 04 Biodiversity and urban space 04-1 Biodiversity 04-2 Urban space development and regeneration 09| Urban planning and governance 9-1 Urban planning and form	- contribution to stormwater / run off regulation in small scale - providing habitats for insects (pollinators), birds - improving local air quality through the trapping of pollutants - increase amount of green spaces for inhabitants - increase diversity in urban areas
Possible negative effects	07| Public Health and well-being 07-3 Health	- presence of undesired insects - produce allergens

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales

Scale at which the NBS is implemented	Object scale According to *Peschardt et al. (2012)* ranging from a few hundred square meters to 5000. In other studies focusing on small parks, the size could be maximum 2500 m^2 (hiv) (Smith (2005) defines a pocket park as one that serves up to a four block radius, with most of the users coming from within a one-two block radius.
Impacted scales	- Object (Neighbourhood only in the case of a large number of pocket parks in one area)

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Usually 1-2 years – it depends on the growth of plants and the establishment of amenities. If it contains trees, it could be longer: 10-15 years.
Life time	Depending on the vegetation of pocket park, can be much more than 10 years – it depends on species, intensity of human usage and activities
Sustainability and life cycle	Sustainability depends largely on the plants used, the possibility of irrigation. It is advisable to choose a wide tolerant and resistant (drought or shade tolerant perennial) species that do not require extensive care. The use of perennials greatly improves sustainability, as after 2-4 years plants can be propagated by division so can be replaced (at minimal cost) the shortages or can be planted in new areas.
Management aspects (kind of interventions + intensity)	Highly depends on climate of the given places. Maintenance works e.g.: - flower and tree planting, grooming, pesticide and herbicide applications, weeding, suppressing invasive plants - One of the most important problems of the maintenance could be irrigation, if it is no possible to build an automatic irrigation system. Planting drought resistant plants minimizes the water usage, but these species are generally hardy in high heat and in soils with poor fertility.


(A) Flowering pocket garden during summer drought without irrigation using native drought-tolerant species (B) shade-tolerant species in sunlight-deficient pocket park in Szeged, Hungary (photo: Ágnes Gulyás)

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	owners, co-owners, local government, residents
Technical stakeholders & networks	urban planners, designers, landscape architects, local green spaces managers, NGO-s, Specialized green spaces management firms and gardeners
Social aspects	It is important to involve the neighbourhood residents into the planning process as well, in order to create the most suitable public space for community needs.

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	The prudent careful planning (taking into account the local conditions) is very important by the creation of pocket parks, because due to the small area (and strong usage) their sensitivity and vulnerability are extremely high. Key points for success: - appropriately adapted plant choice (adapted e.g. frost, drought, strong sunlight/uv radiation, shade, wind, soil character) - if no irrigation system is available, due to the right plant selection, the pocket park's vegetation can survive the dry summer season by using some "emergency" supplemental irrigation - proper soil quality (with plenty of organic matter) incorporated hold moisture better - mulching - keeping competitive weeds out of the pocket park
Materials involved	Wide range of materials: vegetation (trees, shrubs, perennials, annual plants etc.), the pavement materials (wood, stone, concrete, gravel etc), irrigation systems or water harvesting systems

II.5 Legal aspects related
- municipal laws, e.g. urban structure plan, urban building regulations, urban development laws, concepts, strategies, land use planning regulation, park master plan, regulation on the protection of (local) natural values.

II.6 Funding Economical aspects	
Range of cost	The costs depend heavily on the design, the construction of other additional functions (street furniture, play ground etc.), irrigation requirements (and the economic situation of the country). Creation: According to *Cohen et al. (2014)* in Los Angeles the creation cost was ~1000 €/m^2 but in contrast, a courtyard transformation to a pocket garden (private initiative) of an old apartment block in Budapest was significantly less ~ 50 €/m^2 Operation and maintenance: According to *Tempesta (2015):* - Veneto Region, Italy: 0.39 to 2.73 EUR/year/m^2 (constant price 2012); 10.08 EUR/inhabitant/year - 15 UK parks: 0.28 to 1.34 EUR/year/m^2, 10.61 to 44.12 EUR/inhabitant/year (constant price 2002)
Origin of the funds (public, private, public-private, other)	depending on the owner: local government funding, multi-agency public sector funding, marketing income, company-based foundations, donations from private individuals and corporations, non-profit organizations, private foundations, community foundations,

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Because of the high built up ratio some solutions can be applied on the surrounding walls or pavement: climber green walls, living walls systems, mulching, waterfall, small fountain, permeable pavement, urban orchards, rain gardens, insect hotel, composting and overall management strategies like no-use of chemical fertilizers and pesticides, reasoned use of organic fertilizers…

Living wall and waterfall in Greenacre park in Manhatten
http://www.nydailynews.com/life-style/real-estate/east-51st-street-manhattan-micro-nabe-strong-allure-article-1.1043774

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	Success factors could be mainly the same as in the case of bigger urban parks: Design: - establish a sense of place - good visibility and connectivity - design for ease of maintenance - appropriate conditions for socializing - parks are closely tied into the neighbourhoods they serve - sustainable and efficient irrigation system: like rain gardens. Maintenance: - Staff issues (use a staffing a model that works for the organization; ensure goals, standards, and design intent are understood; organize maintenance staff by zone and specialties; develop staff) - Use sustainable maintenance practices (NPS USDI 2007) - sustainable and efficient irrigation system

Limiting factors	- intensive use, extreme human disturbances (e.g. pedestrian, vehicles) - pressures from surrounding urban environment (Jasmani 2013) - littering and misuse of resources (dog mess) - poor management (Nordh and Østby, 2013) - inadequate communication and focus on ecosystem disservices - municipalities ignored the role of local green areas in sustaining species diversity in higher level governance processes
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	empty open space, concrete pavement, lawn
Close NBS	- Public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems -mulching – Insect hotels – Composting – Rain gardens – Vegetable gardens

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Armato F. (2017) Pocket Park: Product Urban design, The Design Journal, DOI: 10.1080/14606925.2017.1352705, pp. 1869-1878

Bitterman N. and Simonov E. (2017): Multisensory design of pocket gardens for reducing stress and improving well-being, performance and satisfaction, The Design Journal, DOI: 10.1080/14606925.2017.1352755, pp. 2418-S2425

Braquinho C., Cvejić R., Eler K., Gonzales P., Haase D., Hansen R., Kabisch N., Lorance Rall E., Niemela J., Pauleit S., Pintar M., Lafortezza R., Santos A., Strohbach M., Vierikko K. and Železnikar Š. 2015: A typology of urban green spaces, ecosystem services provisioning services and demands. GREEN SURGE Report D.3.1, 68 p

Cohen D.A., Marsh T., Williamson S., Han B., Pitkin Derose K., Golinelli D., McKenzie T.L. (2014): The Potencial for Pocket Parks to Increase Physical Activity. Am J Health Promot. 28(3 0): doi:10.4278/ajhp.130430-QUAN-213. pp. 19-26

Dunnett N., Swanwick C. and Woolley H. (2002): Improving Urban Parks, Play Areas and Green Spaces. Department for Transport, Local Government and the Regions, London (UK). 217 p

NPS USDI (National Parks Service, U.S. Department of Interior) (2007): Best Management Practices Used in Urban Parks in National and International Locations. – A background report for the National Mall Plan, Washington D.C.

Nordh, H., Hartig, T., Hagerhall, C. M. and Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. Urban Forestry & Urban Greening, 8(4), 225-235.

Ramirez, P. C. and Zuria, I.,(2011) The value of small urban green spaces for birds in a Mexican city. Landscape and Urban Planning 100, pp. 213-222.

IV.2 Sources used in this factsheet

Jasmani Z, (2013) Small urban parks and resilience theory: how to link human patterns and ecological functions for urban sustainability. For Urban Ecology as Science, Culture and Power course KTH Stockholm, 1-11

Nordh, H. and Østby, K. (2013). Pocket parks for people - A study of park design and use. Urban Forestry & Urban Greening, 12(1), 12-17

Peschardt, K.K. (2014): Health Promoting Pocket Parks in a Landscape Architectural Perspective. IGN PhD Thesis. Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg. 172 p

Tempesta, T (2015): Benefits and costs of urban parks: a review. Aestimum 67, 127–143

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Ágnes Gulyás	SZTE	Writer
María González Ortega	CARTIF	Reviewer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

The **Private garden** is a type of Urban Green Spaces Areas in immediate vicinity of private (privately owned or rented) houses, cultivated mainly for ornamental purposes and/or non-commercial food production (Cvejić et al. 2015; Dewaelheyns et al., 2018). Gardens offer possibilities to sustain and improve ecological and social qualities in people's everyday environment, and they have a potential to support a wide range of ecosystem services (Loram et al., 2008; Tappert et al., 2018). A key element is that the resident/s have autonomy over the garden, so we exclude the open green spaces and communal gardens (with management by committee, local authority), smaller public parks and gardens (pocket gardens) (Cameron et al., 2012). Depending on age and location of cities, domestic gardens contribute to a wide range (between 10 and 36%) of the total urban area (Loram et al, 2007; Mathieu et al., 2007).

Different variants existing

Gardens are highly heterogeneous in forms and functions, and there are many types of groupings.
According to form and size they can be characterize as: <25, 25-50, 50-100, 100-200, 200-400, 400-800, >800 m^2. Percentage of gardens in different size categories of the cities depends on the age, structure of the city (Loram et al, 2007).
According to functions, they can be categorized by:

- **edible garden**: garden growing edible plants (fruits, vegetables, nuts trees, herbs*)
- **ornamental garden**: An ornamental garden uses plants that are designed for their aesthetic pleasure and appearance. Its design includes flowering plants and bulbs in addition to foliage plants**, ornamental grasses***, shrubs and trees.
- **special garden**: garden with a specific function (e.g. organic garden****, container garden, greenhouse garden, shade garden, garden for arid conditions with drought tolerant grasses, xeriscape flowers, perennials, shrubs and trees, slope and hillside garden, accessible garden for example sensory gardens for the blind, wheelchair accessible gardens for the handicapped, rain garden)

*Herbs garden**
http://herbgardening.com/

*Traditional rose-breeding family's garden** in Szeged, Hungary*
www.kerthelyseg.hu

*Ornamental grass*** (zebra grass) garden in Southern California*
https://www.lowes.com

*Small organic garden**** in gardening box*
https://bioenergetic.hu

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and Urban Place 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 07| Public Health and well-being 07-2 Quality of Life 11| Green Economy 11-3 Direct economic value of NBS	-increasing the green area (with vegetation) - Improve the quality of the urban environment and of soil -Active recreation, reduced stress -aesthetic value - Can provide a sustainable system of food sources
Co-benefits and challenges foreseen	01| Climate issues 01-1 Climate Mitigation 01-2 Climate adaptation 02| Urban water management and quality 02-1 Urban water management 04| Biodiversity and Urban Place 04-1 Biodiversity 06| Resource efficiency 06-1 Food, energy and water	-Carbon sequestration by vegetation -Reduce the urban heat island effect - Moderate contribution to stormwater / runoff regulation - Provide a habitat for birds and pollinating insects -According to food supply chain is requires less transport and logistic system
Possible negative effects	02| Water management 02-1 Urban water management and quality	- the increased utilization of water in summer period -water contamination

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales

Scale at which the NBS is implemented	Object, district, neighbourhood
Impacted scales	The scales impacted are in most of case limited. It concerns the district itself or the close neighbourhood.

II.2 Temporal perspective (including management issues)

Expected time for the NBS to become fully effective after its implementation	1 -5 years => It depends on the types of the grown vegetables or plants.
Life time	The lifetime depends on type of vegetation (longer with trees).
Sustainability and life cycle	Depending on the type of the vegetation, it requires different intensity maintenance, and sustainability highly depends on its location, climatic aspects and the chosen plants. For the sake of sustainability it is generally

	necessary to improve soil (composting), irrigation (preferably local collected rainwater) and mulching (reduce the amount of water that evaporates from soil and acts as an insulating layer on top of soil, keeping it cooler in the summer).
Management aspects (kind of interventions + intensity)	Highly depends on climate of the given places. Maintenance works e.g.: - flower and tree planting, grooming, pesticide and herbicide applications, weed control, suppressing invasive plants - One of the most important problems of the maintenance could be irrigation, if it is not possible to build an automatic irrigation system. Planting drought resistant plants minimizes the water usage, but these species are generally hardy in high heat and in soils with poor fertility.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- owners, co-owners (in case of a joint ownership property) - tenants - eventually neighbour or municipality
Technical stakeholders and network	- specialized green spaces management firms - horticulturist and gardeners - landscape architects
Social aspects	- green solutions are popular in the participative processes - in semi-private gardens the formation of community can be emerged, or it can be strengthen due to the collective work
II.4 Design / techniques/ strategy	
Knowledge and know-how involved **Or key points for success**	The prudent careful planning, taking into account the local conditions (climate, soil etc.) is very important by the creation of a sustainable private garden. Key points for success: - appropriately adapted plant choice (adapted e.g. frost, drought, strong sunlight/uv radiation, shade, wind, soil character) - sustainable irrigation system - proper soil quality (with plenty of organic matter) incorporated hold moisture better - mulching - weed control
Materials involved	- different type of plants (vegetables, flowers, herbs) - containers - irrigations system - garden tools (fence) - water tank for rain water
II.5 Legal aspects related	
- specific rules of municipality	
II.6 Funding Economical aspects	
Range of cost	Investment: 10-100€ / m² It depends on the quality of the soil, the irrigation need, and selection of the plants. Maintenance only the watering fee, other maintenance is overhead.
Origin of the funds (public, private, public-private, other)	- Depending on the owner (or community).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- garden irrigation system combined with solar energy  *Solar irrigation system in private garden* *www.irrigartia.com*

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- appropriate plant choice - self-sufficiency - soil improvement
Limiting factors	- regularly needs of maintenance - unfavourable environmental conditions (poor soil quality, frequent drought etc.) - invasive pressure - the community motivation decreasing (in semi-private gardens)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	No
Close NBS	Urban farm, Urban vineyard, Vegetables garden, Urban orchard, Composting, Soil melioration, Mulching, Insect hotels, Beehives Rain/infiltration gardens

IV/ References

Note: references presented below are often common with the whole category …

IV.1 Scientific and more operational references (presented jointly)
Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., Strohbach, M.W., 2015. A typology of urban green spaces, ecosystem services provisioning and demands. Report of the GREEN SURGE project, Report D.3.1, 68 p Cameron R.W.F., Blanuša T., Taylor J.E., Salisbury A., Halstead A.J., Henricot B. and Thompson K. (2012): The domestic garden –Its contribution to urban green infrastructure, Urban For. Urban Greening, 11, pp.

129-137

Hunter, M.C.R ., Brown, D.G. (2012) Spatial contagion: gardening along the street in residential neighborhoods. Landsc. Urban Plan. 105, pp. 407–416

Mathieu, R., Freeman, C., Aryal, J., 2007. Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. Landscape and Urban Planning 81, pp. 179-192.

Tappert S., Klöti T. and Drilling M., (2018): Contested urban green spaces in the compact city: The (re-) negotiation of urban gardening in Swiss cities. Landscape and Urban Planning 170, pp. 69-78

IV.2 Sources used in this factsheet

Coolen H. and Meesters J., (2012): Private and public green spaces: meaningful but different settings. Journal of Housing and the Built Environment, Volume 27, Issue 1, pp 49-67

Dewaelheyns V., Jakobsson A. and Saltzman K (2018): Strategic gardens and gardening: Inviting a widened perspective on the values of private green space. Urban For. Urban Greening, https://doi.org/10.1016/j.ufug.2017.12.009

Loram, A., Tratalos, J., Warren, P.H., Gaston, K.J., 2007. Urban domestic gardens (X): the extent & structure of the resource in five major cities. Landscape Ecology 22, 601-615.

Loram, A., Warren, P.H., Gaston, K.J., 2008. Urban domestic gardens (XIV): the characteristics of gardens in five cities. Environmental Management 42, 361-376.

V/ Authors

Name	Institution / company	Writer/ reviewer
Ágnes Gulyás	SZTE	Writer
Marjorie Musy	Cerema	Reviewer

> PUBLIC URBAN GREEN SPACES (PLACES, SQUARES etc.)

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Smaller (smaller than large urban parks), open, natural, semi-natural or planted public spaces within a city (belongs to the category of Recreation Green Spaces that are a part of Amenity Green Space), accessible to the general public and aside for human enjoyment and recreation (Bell et al., 2007; Coolen and Meesters 2012; Cvejić et al 2015). It has some of active and passive recreational facilities, fountains, street arts, that meet the recreation and social needs of the residents of and visitors to the city (Haaland and Bosch, 2015; Kaczynski and Henderson, 2008) .

Different variants existing

Their size (and function) can be very variable, between the scale of pocket park and large urban park.

- **Square (plaza):** Mainly paved easyly accessible open space with amenities including seating (e.g. steps, ledges, benches, chairs & tables), commonly surrounded by built up structures, for direct public use and with permeable area less than 40%. Divided subcategories: *mineral squares**, *squares with trees***, and *green squares****, whose permeability respectively corresponds to the intervals 0-5%, 5-15% and 15-40% (Farinha-Marques et al., 2012) Squares are often exposed to very intense use, and they give rise to various social activities (e.g. celebrations, festivals) (Byrne and Sipe, 2010)
- **Allotment******: Small garden parcels cultivated by different people, intended for non-commercial food production and recreation (some of definitions include in allotment community gardens and urban farms, but according to NBS analysis these type of NBS were separately discussed)
- **Neighbourhood green space**: Smaller (0,1- 4 ha) semi-public or public green spaces, vegetated by grass, trees and shrubs in multi-story residential areas.
- **Amenity green space**: most commonly, but not exclusively in housing areas, including informal recreation spaces, communal green spaces in and around housing. Informal recreation spaces and green spaces in and around housing, with a primary purpose of providing opportunities for informal activities close to home or work.(Hansen et al., 2017)

Old Market Square in Nottingham, Great Britain*
http://www.spacesyntax.com/project/nottingham-old-market-square/

*Rathaus Platz** in Freiburg am Breisgau, Germany*
http://bz-ticket.de/rathausplatz-freiburg

*Central green square*** of Szeged (Dugonics square) with strong anthropogenic use (Photo: Agnes Gulyas)*

*Allotment garden**** in Freiburg im Breisgau,Germany https://www.deutsche-digitale-bibliothek.de/item/YMXFR7DGQRV7CXKVIUTM4QF6TKTBWGNT*

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues 01-1 Climate mitigation 01-2 Climate adaptation 07| Public Health and well-being 07-2 Quality of Life 08| Environmental justice and social cohesion 08-2 Social cohesion	- carbon sequestration - reducing the temperature and regulate the microclimate at neighbourhood and object scale - reducing heat stress - increasing physical activity, improving/supporting health, well-being, moderate stress - provide leisure, sport and recreation facilities - facilitate social interaction and community attachment, interaction among neighbours, promote social cohesion
Co-benefits and challenges foreseen	02| Urban water management and quality 02-1 Urban water management 03| Air quality 03-2 Air quality locally 09| Urban planning and governance > 9-1 Urban planning and form 11| Green economy > 11-3 Direct economic value of NBS	- moderate contribution to stormwater / runoff regulation - ground water recharge - reduced particulate pollution - increase diversity in urban areas - attractive to tourists
Possible negative effects	07| Public Health and well-being 10| People security	- squares without trees and pervious pavement have unpleasant microclimate, strong heat stress - Due to their location near streets, squares can be vey noisy and polluted - Presence of undesired behaviour (crime)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales

Scale at which the NBS is implemented	Object District/Neighbourhood scale Depending on the type
Impacted scales	- Object, District/Neighbourhood - City: some impacts take a wider area than where it is implemented, e.g. social interaction

II.2 Temporal perspective (including management issues)

Expected time for the NBS to become fully effective after its implementation	Usually 1-5 years – it depends on the growth of plants and the establishment of amenities. Considering the growth of trees, it could be longer: 10-15 years. Some of its benefits (e.g. significant air quality change, social habit change, health benefits) will take longer than 5 years to be fully realised. Although there are some short-term effects, green space interventions need to be considered as an urban investment that delivers the strongest benefits over a longer time period.
Life time	More than 10 years – it depends on species, control over and responsible management of species and amenities, as well as resource depletion coming from human activities
Sustainability and life cycle	The prudent, careful planning (taking into account the local conditions) is very important by the creation of urban green spaces. Sustainability depends largely on this and the possibility of irrigation. The intensity of the use of the square can also strongly impact it's sustainability.
Management aspects (kind of interventions + intensity)	Because of the very heterogeneous group, the challenges of maintenance are very different, and highly depends on climate and usage intensity of the given places. Maintenance works e.g.: - flower and tree planting, mowing, grooming, pesticide and herbicide applications, weed control, suppressing invasive plants - automatic irrigation systems (if it is possible) - planting drought resistant plants minimizes the water usage, but these species are generally hardy in high heat and in soils with poor fertility.

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	owners, co-owners, municipality decision-makers, green spaces management firms
Technical stakeholders & networks	urban planners, designers, landscape architects, ecologists, local green spaces managers, NGO-s, horticulturists and gardeners
Social aspects	- It is important to involve the owners, residents in planning, and sometimes the maintenance - scientific research opportunities

II.4 Design / techniques/ strategy

Knowledge and how-know involved	Important for the sustainability: - appropriately adapted plant choice (adapted e.g. frost, drought, strong sunlight/uv radiation, shade, wind, soil character) - choice wide tolerant and resistant (drought or shade tolerant perennial) species that do not require extensive care. The use of perennials greatly improves sustainability, as after 2-4 years plants can be propagated by division so can be replaced (at minimal cost) the shortages or can be planted in new areas. - if no irrigation system is available, due to the right plant selection, not too much added irrigation is needed - proper soil quality (fertilising) - mulching - weed (and invasive) control
Materials involved	Wide range of materials: vegetation (trees, shrubs, perennials, annual plants etc.), the pavement materials (wood, stone, concrete, gravel etc)

II.5 Legal aspects related

Depends on the type of public green space.

II.6 Funding Economical aspects	
Range of cost	Costs can vary widely depending on the specific characteristics of the area, the type of green spaces and choice of plants, on the design, the construction of other additional functions (street furniture, play ground etc.), irrigation requirements (and the economic situation of the country). *Cost for example according to Tempesta (2015):* - Veneto Region, Italy: 0.39 to 2.73 EUR/year/m^2 (constant price 2012); 10.08 EUR/inhabitant/year - 15 UK parks: 0.28 to 1.34 EUR/year/m^2, 10.61 to 44.12 EUR/inhabitant/year (constant price 2002)
Origin of the funds (public, private, public-private, other)	Public or Public-private partnerships National and local government funding, multi-agency public sector funding, marketing income, donations from private individuals and corporations, nonprofit organizations, conservancies, private foundations, community foundations, company-based foundations (Merk et al., 2010)

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- hedge and planted fences, vegetated pergolas - blue infrastructure - solar panel - sustainable irrigation system - permeable pavement (combined with structural soil) - conventional solutions: several types of pavement

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Involving local residents in design and construction - Restricting planning to functions that match the size and capacity of the urban green space - Ensuring adequate and frequent maintenance and cleaning - Avoiding the establishment of “event places” that attract too many customers (unless the size is sufficient for this) - Access to routes and litter bins, toilets and water supply - Design for ease of maintenance
Limiting factors	- Problems deriving from intensive anthropogenic use, e.g. vehicles, dogs, littering, especially in squares - Safety issues, vandalism and fear of crime especially in squares - owners motivation decreasing - limitations of accessibility - pressures from surrounding urban environment

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- permeable pavement* - artificial shading** - rainwater harvesting - infiltration trenches

	 *Permeable pavement* in a parking place http://www.greenne.com/case-permeable-paving/*	 *Sun sails as artificial shading** in Tel Aviv, Israel (photo: Ágnes Gulyás)*
Close NBS	- urban parks, public urban green spaces with specific uses, green cemeteries, pocket gardens, private gardens - choice of plants, hedge and planted fences, vegetated pergolas, flower fields, woods, lawns, single trees, street trees, green roofs, climber green walls, living walls systems, build or attached planter systems - composting - mulching	

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Bell S., Montarzino A., Travlou P. (2007). Mapping research priorities for green public urban space in UK. Urban Forestry and Urban Greening, 6, 2: 103 – 115

Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., Strohbach, M.W., 2015. A typology of urban green spaces, ecosystem services provisioning and demands. Report of the GREEN SURGE project, Report D.3.1, 68 p

Haaland, C. and Bosch, C.K. (2015) Challenges and strategies for urban green-space planning in cities undergoing densification: a review, Urban Forestry and Urban Greening, pp. 760-771

Kaczynski A.T., Henderson K.A. (2008) Parks and recreation settings and active living: a review of associations with physical activity function and intensity. J Phys Act Health. Jul; 2008 5(4):619 – 632. [PubMed: 18648125]

Merk, O., Saussier, S., Staropoli, C., Slack, E., Kim, J-H (2012): Financing Green Urban Infrastructure, OECD Regional Development Working Papers 2012/10, OECD Publishing; http://dc.doi.org/10.1787/5k92p0c6j6r0-en

IV.2 Sources used in this factsheet

Byrne J. and Sipe N. (2010): Green and open space planning for urban consolidation – A review of the literature and best practice. Urban Research Program, Griffith University Brisbane, QLD 4111 www.griffith.edu.au/urp

Coolen H. and Meesters J., (2012): Private and public green spaces: meaningful but different settings. Journal of Housing and the Built Environment, Volume 27, Issue 1, pp 49-67

Farinha-Marques P., Fernandez C., Lameiras J.M., Silva S., Leal I. and Guilherme F. (2012): Green space typologies in the city of Porto. EURAU'12

Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (eds., 2017). Urban Green Infrastructure Planning: A Guide for Practitioners. Retrieved from http://greensurge.eu/working-packages/wp5

Tempesta, T (2015): Benefits and costs of urban parks: a review. Aestimum 67, 127–143

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Ágnes Gulyás	SZTE	Writer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	An urban single tree in a NBS context is an individually standing tree (independently of its age), which is recorded and managed independently from the other elements of the surrounding vegetation (e.g. trees of a nearby park). A single tree stands on an extended unsealed surface (in contrast to street trees). From the point of view of most of the urban challenges, small trees (<~2m) are functioning similarly to hedges and shrubs, thus they can be included in those categories.

Different variants existing

Most of the processes related to NBS functioning differ for deciduous and coniferous trees, which are distinguished in many NBS-related studies.

- **Deciduous trees:** the leaf senescence and death have considerable effect on many urban challenges-related effects (e.g. due to lower leaf area, shading effect or dry deposition of pollutants are lower during the winter period)
- **Coniferous trees:** in case of those services, which have high relevance at certain times of the year, the presence of leaves may cause an outstanding importance in NBS performance for coniferous tree species

Deciduous urban single tree

@SZTE

Coniferous urban single tree

https://austinbotany.wordpress.com

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues >01-1 Climate adaptation >01-2 Climate mitigation 07| Public health and well-being > 07.-2 Quality of life	- carbon sequestration - reducing the temperature and regulating the microclimate at the object scale (heat stress mitigation) by evapotranspiration and shading - aesthetic value - cognitive development, improvement of opportunities for exploration by children (reconnecting children with nature) - education, environmental education
Co-benefits and challenges foreseen	02| Urban water management and quality 03| Air quality 04| Biodiversity and Urban Space 05| Soil management 06| Resource efficiency 08| Environmental justice and social cohesion	- interception of stormwater - dry deposition of air pollutants - providing habitat for several species, promoting biodiversity - reducing the erosion caused by water run-off, Increase in soil organic matter - provide shading for buildings - facilitating social interaction and community attachment, interaction among neighbours, promoting social cohesion
Possible negative effects	07| Public Health and well-being > 07.-3 Health	- in some cases: providing habitat for undesired insect species - in some cases: producing allergens and contributing to air pollution through the emission of biogenic volatile organic compounds (BVOC) - falling branches might cause human injuries

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Object scale
Impacted scales	Neighbourhood

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	- 5-10 years - the growth of the trees (and thus the time when they reach the fully effective state in terms of provisioning ecosystem service) is highly dependent on species characteristics
Life time	- more than 10 years - although the theoretical life times of many tree species are high (might be above 100 years), the urban circumstances (heat stress, polluted air, limited water availability in the soil, etc.) and management interventions result in a much shorter life-span of urban trees
Sustainability and life cycle	- single trees are important elements of the cultural landscapes of the cities, but special sustainability or life cycle aspects are not connected to them

Management aspects (kind of interventions + intensity)	- Management activities: pesticides and herbicides applications, watering, raising of saplings, mulching, pruning, removing leaf litter - Determining the optimal time of tree cut is a complex question: ecosystem service provision is still high at high ages, but management activities and potential damages are much higher too  Tree pruning (Kiskunfélegyháza, Hungary) http://felegyhazikozlony.eu  Tree watering (Budapest, Hungary) www.fokert.hu

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	Communication between stakeholders and common decision-making about single trees are often a place of land use conflicts: for example, nearby inhabitants may call for preservation of "symbolic" old-growth trees, which is often in conflict with some technical aspects such as dangerousness of the tree or planned building activities.
Technical stakeholders & networks	Urban planners, landscape architects, ecologists, local green spaces managers, nonprofit organizations, power supplier and other infrastructure companies
Social aspects	- Single trees which stand in important, highly used urban open spaces can have quite high recreational and other cultural values, and thus have an "inherent" social value - The importance of single trees might also be communicated to the inhabitants. As they have several ecosystem services which are easy to communicate, they can be a suitable place for environmental education activities.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	Aspects of urban tree selection: • Site characteristics and natural distribution - Climatic characteristics (e.g. late frost risk, light regime) - Soil conditions (e.g. soil depth, soil moisture, soil compaction risk) - Natural distribution • Tree appearance - Habitus (e.g. maximum tree height, growth speed, crown shape) - Leaf (e.g. shape, autumn coloring) - Blossom (e.g. color, odor) - Fruit (e.g. color) • Ecosystem services - e.g. honey plant, edibility, particulates absorption) • Required management activities (maintenance, potential undergrowth) • Risks and interferences (e.g. allergy potential, toxicity, damages by roots) *(Vogt et al. 2017)* Correct and up-to-date urban single tree inventories are needed for NBS-based management of urban trees. Besides data about the sizes of the trees, these datasets should contain parameters that are important for the assessment of ecosystem services (e.g. health status) *(Takács et al. 2015)*. The creation and maintenance of these databases can be facilitated and improved with the help of airborne or terrestrial laser scanning *(Saarinen et al. 2014)*.

Materials involved	Artificial objects are not needed in the surroundings, or for the functioning of single trees.

II.5 Legal aspects related

If a single tree needs special protection, it can be named as a protected tree (in a decree by the local council).

II.6 Funding Economical aspects

Range of cost	*Soares et al. 2011 (Lisbon, Portugal):* - Tree management costs: 29,5 $/tree - Administration costs: 9,93 $/tree - Other costs: 6,2 $/tree *McPherson 2003 (Modesto, California, USA):* - Prune: 6-30 $/tree - Remove: 0,9-3,5 $/tree - Plant: 0,01-2,2 $/tree - Root-related: 0,1-2,15 $/tree - Storm/liability: 0,02-0,76 $/tree - IPM/other: 0,09-0,92 $/tree
Origin of the funds (public, private, public-private, other)	All kinds of funds are relevant, but trees in bigger stands (woods and parks) might be preferred by publicly funded tree managers for economic reasons. Single trees with high relevance for local inhabitants might be managed (and funded) by them (privately).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Single trees can be planted/maintained near urban parks or public spaces.

A single tree in Greenwich Park
www.foap.com

Trees in a playground (Celldömölk, Hungary)
www.ips-gyermekszem.hu

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Best practices in tree maintenance and urban forestry in general: - Strategic plan with goals - Wood and green waste recycling - Water conservation - Drought Tolerant Species Planting - Concrete/Soil Program - Certified Arborists *(Remien 2016)*
Limiting factors	Barriers to preserving urban trees: • Institutional barriers: - Insufficient funds - Unprofessional maintenance measures undertaken by greenery managers (e.g. drastic pruning) - Lack of local spatial management plans - Regulations which downplay the significance of urban greenery or limit the possibility to protect - Unprofessional actions of contractors maintaining trees and shrubs - etc. • Social barriers - Societies perceives other issues as more pressing (e.g. parking lots, building) - Trees are perceived as a problem (e.g. shade, allergies, need to clean up leaves) - Lack of awareness of the significance of trees among residents - Individual persons' bad habits (e.g. tree topping) - Lack of knowledge on the possibilities and ways of preventing tree damage - etc. *(Kronenberg 2012)*
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Empty open space, playground with concrete pavement
Close NBS	- public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), - choice of plants, flower fields, woods, lawns, - composting

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Roloff A. (ed.) (2016): Urban Tree Management: For the Sustainable Development of Green Cities. John Wiley & Sons Ltd.

Song X.P., Tan P.Y., Edwards P., Richards D. (2018): The economic benefits and costs of trees in urban forest stewardship: A systematic review. Urban Forestry & Urban Greening 29, 162-170.

Vogt J., Hauer R.J., Fischer B.C. (2015): The Costs of Maintaining and Not Maintaining the Urban Forest: A Review of the Urban Forestry and Arboriculture Literature. Arboriculture & Urban Forestry 41, 293-323.

IV.2 Sources used in this factsheet

Kronenberg J. (2012): Barriers to preserving urban trees and ways of overcoming them. Sustainable Development Applications no 3.

McPherson E.G. (2003): A benefit-cost analysis of ten street tree species in Modesto, California, U.S. Journal of Arboriculture 29, 1-8.

Remien S. (2016): A Comparative Study of Urban Forest Management Programs for Three Major Cities in Santa Clara County: A Benchmarking Study. Master's Project. 469.

Saarinen N., Vastaranta M., Kankare V., Tanhuanpää T., Holopainen M., Hyyppä J., Hyyppä H. (2014): Urban-Tree-Attribute Update Using Multisource Single-Tree Inventory. Forests 5, 1032-1052.

Soares A.L., Rego F.C., McPherson E.G., Simpson J.R., Peper P.J., Xiao Q. (2011): Benefits and costs of street trees in Lisbon, Portugal. Urban Forestry & Urban Greening 10, 69-78.

Takács Á., Kiss M., Tanács E., Varga L., Gulyás Á. (2015): Investigation of tree stands of public spaces in Szeged. Journal of Environmental Geography 8, 33-39.

Vogt J., Gillner S., Hofmann M., Tharang A., Dettmann S., Gerstenberg T., Schmidt C., Gebauer H., Van de Riet K., Berger U., Roloff A. (2017): Citree: A database supporting tree selection for urban areas in temperate climate. Landscape and Urban Planning 157, 14-25.

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Pyrène Larrey-Lassalle	Nobatek	Reviewer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Woods are groups of trees (or areas of land, covered with trees), which are independent from a bigger urban park or other public urban green space. Woods do not have any special function in the life of urban inhabitants (botanical exhibition, cemetery, etc.), and may also contain smaller trees, e.g. in a growing phase. The number of adjacent trees can help to differentiate from single trees, while parks often have special status in local urban environmental management or spatial planning (which is not the case for woods).

Different variants existing

Woods "summarize" the effects of trees that they consist of. As single trees, which can be grouped into the two main categories (which determine many aspects of NBS performance) of deciduous and coniferous trees, woods can also be classified into:

- **Woods containing deciduous trees:** because of leaf senescence and death, leaf surface is lower in winter, resulting in the decrease of the efficiency of the processes which depend on this parameter (e.g. air pollution removal, interception)
- **Woods containing coniferous trees:** coniferous tree stands can sometimes be characterized with a lower amount of light at lower layers, and the presence of leaves throughout the whole year results in a nearly constant provisioning ecosystem service

Woods containing deciduous trees

https://elmenykepek.wordpress.com

Woods containing coniferous trees

http://coyot.es/reconcilitationecology

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues >01-1 Climate adaptation >01-2 Climate mitigation 02| Water management > 02-1Urban water management and quality > 02-2 Flood management 04| Biodiversity and Urban Space > 04-1 Biodiversity 05| Soil management > 05-1 Soil management 07| Public health and well-being > 07.-2 Quality of life > 07.-3 Health 09| Urban planning and governance	- sequestering atmospheric carbon dioxide - reducing the temperature and regulating the microclimate at the object scale (heat stress mitigation) by evapotranspiration and shading - intercepting of stormwater and reducing run-off - providing habitat for several species, promoting biodiversity - reducing the erosion caused by water run-off, wind speed (losing soil matter), Increase in soil organic matter - aesthetic value, cognitive development, improvement of opportunities for exploration by children (reconnecting children with nature) - increasing physical activity, well-being, and improving/supporting health, moderating stress - limiting urban sprawl in the case of green belt
Co-benefits and challenges foreseen	03| Air quality 06| Resource efficiency 07| Public health and well-being 08| Environmental justice and social cohesion 11| Green economy	- air pollution removing, best local air quality - providing wood for heating or as a construction material - acting on sound propagation and perception - facilitating social interaction and community attachment, interaction among neighbours, promoting social cohesion - value of wood, employment for wood exploitation
Possible negative effects	07| Public Health and well-being > 07.-3 Health 10| People security > 10.-1 Control of crime	- in some cases: providing habitat for undesired insect species - in some cases: producing allergens and contributing to air pollution through the emission of biogenic volatile organic compounds (BVOC) - falling branches might cause human injuries - wood can create areas difficult to supervise

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Object and neighbourhood scale
Impacted scales	Neighbourhood

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	- 5-10 years - the growth of the trees is different between species, and the tree stand's full capacity (e.g. the time when shades are overlapping) is difficult to determine. Generally, it can be estimated as the sum or average of the characteristics of the constituent species.
Life time	- more than 10 years - though in a diverse stand of trees, the lifetimes might be quite different, the single trees in woods are often managed similarly
Sustainability and life cycle	- woods may have outstanding importance for the local inhabitants, but special sustainability or life cycle aspects are not connected to them
Management aspects (kind of interventions + intensity)	- Management activities: pesticides and herbicides applications, raising of saplings, mulching, pruning, removing leaf litter - In most cases, woods are not handled as separate elements of urban green infrastructure, rather as single trees standing together. Thus they are not assigned special management programs and interventions, they are just treated as a group of single trees. Consequently, the aspects of management intensity can be considered the same as in the case of trees: lower management intensity (e.g. in terms of longer rotation cycles, avoiding clearcuts of whole stands, etc.) seems to improve NBS performance *(Kiss et al. 2015)*. Being a (sometimes bigger) stand, the trees in woods are not given as many observance and management.  Pruning of deciduous trees in woods http://www.arborological.com  Mowing and leaf collecting in woods www.ventrac.com

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	From the point of view of decision-making processes and stakeholder involvement, woods can be characterized with mainly similar aspects like larger urban parks. A bigger group of trees is presented in masterplans and other urban spatial planning documents, thus they can be considered as "territorial elements" in the urban land cover (with special rules, sometimes territorial protection), most of which are not relevant for single trees. Meanwhile, many stakeholder involvement-related questions that arise in case of urban trees are relevant for woods as well (e.g. as tree stands are sometimes quite important parts of the inhabitants' sense of place, their management can be source of local land use conflicts). This highlights the need for participative decision-making in the case of these NBS entities as well.
Technical stakeholders & networks	Urban planners, landscape architects, ecologists, local green spaces managers, non-profit organizations, power supplier and other infrastructure companies
Social aspects	- Woods may be large enough to serve as recreational places for nearby inhabitants. As such, the possibly emerging social aspects might be connected to them: questions of accessibility, suitable quality/aesthetics of the green space, etc. *(Kothencz et al. 2017, Zhang et al. 2017)* - If woods are in a good state and easy to access, they can accommodate environmental education activities.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	Some possible aspects of park tree species selection: • Identifying plantable and non-plantable locations for trees • Policy strategies and other framework information • Environmental and cultural constraints • Economic and social criteria • Tree placement for uneven age structure • Tree placement for species diversity Some examples for ecological and biogeographical criteria: Habitat (incl. food, nesting, etc.), origin, climate condition, soil type, water regime, % tree density/cover, species diversity index, landscape networks *(Behrens 2011)*
Materials involved	No special materials are needed for maintaining urban woods.

II.5 Legal aspects related

Urban woods can be preserved, through territorial protection, which can be declared by the local council.

II.6 Funding Economical aspects

Range of cost	Annual (planting/maintenance) costs (cost/tree): - 28 $ *(Millward and Sabir 2011)* - 22 $ *(Pothier and Millward 2013)* - 0,84 $ *(Sunderland et al. 2012)* - 2.18 $ – 21.80 $ *(Donovan and Butry 2009)*
Origin of the funds (public, private, public-private, other)	Woods consist of a larger number of trees, which are financed mainly from public sources. If the woods are situated in a private property, private funds might emerge.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Woods may provide a suitable (wider) environment for recreation-oriented open spaces, e.g. playgrounds, sportfields

Playground on the border of woods
www.kolyokter.hu

Woods and constructed wetland
www.pinterest.com

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Success and limiting factors are mainly the same as in the case of bigger urban parks: Some elements of best practices: • Landscape Standards: - Align uses and standards with park mission and vision - Use written landscape quality standards • Design: - Establish a sense of place - Control circulation and access - Design to accommodate events and regular use with less impact - Design for ease of maintenance • Maintenance: - Staff issues (use a staffing a model that works for the organization; ensure goals, standards, and design intent are understood; organize maintenance staff by zone and specialties; develop staff) - Develop plans for regular and emergency maintenance - Use sustainable maintenance practices *(NPS USDI 2007)*
Limiting factors	Limiting factors are mainly the same as in the case of urban trees in general: institutional barriers (insufficient funds, unprofessional maintenance measures, etc.) and social barriers (perceiving trees as a problem, pressing other issues, etc.) *(Kronenberg 2012)* In addition, small urban woods sometimes do not have a special status in the urban spatial planning system, which results in the fact that they are not given enough attention in the relevant processes (e.g. can not be named as protected areas, inadequate maintenance efforts, etc.)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Empty open space, lawn, concrete pavement
Close NBS	- public urban green spaces (squares, etc.), public urban green spaces with specific uses (school playgrounds, camp grounds, sport fields, etc.), - choice of plants, flower fields, lawns, large urban public parks

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Garvin A. (ed.) (2011): Public Parks: The Key to Livable Communities. W.W. Norton & Company

Roloff A. (ed.) (2016): Urban Tree Management: For the Sustainable Development of Green Cities. John Wiley & Sons Ltd.

IV.2 Sources used in this factsheet

Behrens F.M-L. (2011): Selecting public street and park trees for urban environments: the role of ecological and biogeographical criteria. PhD Thesis, Lincoln University.

Donovan G.H., Butry D.T. (2009): The value of shade: estimating the effect of urban trees on summertime electricity use. Energy and Building 41, 662-668.

Kothencz Gy., Kolcsár R., Cabrena-Barona P., Szilassi P. (2017): Urban Green Space Perception and Its Contribution to Well-Being. International Journal of Environmental Research and Public Health 14(7). pii: E766. doi: 10.3390/ijerph14070766.

Kronenberg J. (2012): Barriers to preserving urban trees and ways of overcoming them. Sustainable Development Applications no 3.

Millward A.A., Sabir S. (2011): Benefits of a forested urban park: What is the value of Allan Gardens to the city of Toronto, Canada?. Landscape and Urban Planning 100, 177-188.

NPS USDI (National Parks Service, U.S. Department of Interior) (2007): Best Management Practices Used in Urban Parks in National and International Locations. – A background report for the National Mall Plan, Washington D.C.

Pothier A.J., Millward A.A. (2013): Valuing trees on city-centre institutional land: an opportunity for urban forest management. Journal of Environmental Planning and Management 56, 1380-1402.

Sunderland T., Rogers K., Coish N. (2012): What proportion of the costs of urban trees can be justified by the carbon sequestration and air-quality benefits they provide? Arboricultural Journal 34, 62-82.

Zhang Y., Van den Berg A., Van Dijk T., Weitkamp G. (2017): Quality over Quantity: Contribution of Urban Green Space to Neighborhood Satisfaction. International Journal of Environmental Research and Public Health 14, 535; doi:10.3390/ijerph14050535

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> Public green space with specific uses (schools, playgrounds, camp grounds, sport fields)

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS is an urban green space with specific uses in densely built-up urban areas that loosens urban fabric. The patterns of usage of public spaces – places and squares – are to a large extent set by cultural values and habits as well as social status, sex et cetera that rather change in time. People in different countries have different attitudes to public areas and the actual settings reflect such differences in needs, demands and practices. Americans and Brits tend to spend their lunch in the small green areas in front of their offices whereas people in Central Europe use parks rather as weekend recreation and rarely compared to the situation in Western Europe. Northerners spend their times more actively whereas people from the south opt rather for resting. In some areas, open green spaces are seen as threats as it gives shelter to undesired activities and functions, consequently, they are fenced and closed for the night. The patterns also change with time, especially in East-Central Europe. During communism and in the decades after, people tended to use less such facilities in urbanised areas as social gatherings used to be regarded as an act against the power. Moreover, people had strong ‘stayinghome’ attitudes (Konrád-Szelényi, 1969), also favoured by the communist system, compared to the ‘going-out’ attitudes of periods preceding communist rule and present times.

Different variants existing

Five kinds of this NBS can be identified, depending on the functions:

=> Gardens of various institutions

Budapest University of Technology and Economics, Budapest
Source: http://tehetseg.bme.hu/?tema/585

Garden Fitness Program in South - Pest Hospital, Budapest
Source: https://divany.hu/szuloseg/2011/09/05/korhazfigyelo_del-pesti_korhaz_a_pozitiv_meglepetes/

School - garden program in Győr, Hungary
Source: http://www.iskolakertprogram.hu/az-iskolakert-funkcioi/

=> Camp grounds

Zugliget Camping in Budapest, in an old traimway station
Source: http://mapio.net/pic/p-65916437/

Camping Village Roma
Source: http://roma.top-hotelek.hu/szalloda/camping-village-roma/

The Tentstation campground is just five minutes from central Berlin's main Hauptbahnhof train station. Photo by IgoUgo.

=> Play Ground

Zöld Péter Népmese (Green Peter Folktale) Play Ground, Budapest
Source: http://epiteszforum.hu/ujra-megnyilt-a-zold-peter-jatszoter

Play Ground Retek street in Szeged, Hungary
Source: http://www.evangelikus.hu/taxonomy/term/6182

=> Sports Fields

Horse Farm in Budapest, Hidász street
Source: https://hoofpick.net/2196

Vasas Sport Field
Source: https://www.magyarfutball.hu/hu/stadion/482

=> Community Gardens		
 *KÉK Community Gardens, Budapest* *Source: http://lakatlan.kek.org.hu/kek-kozossegi-kertek/index.html*		
I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality 02-1 Urban water management and quality 02-2 Flood management 04| Biodiversity and urban space 04-2 Urban space development and regeneration 07| Public health and well-being 07-2 Quality of life 07-3 Health 08| Environmental justice and social cohesion 09| Urban planning and Governance 09-1 Urban planning and form	- Contributing to storm water management and to water evaporation - Ensuring the proximity to green areas - Better distribution of green areas in the core areas - Proposing spaces for outdoor activities - Offering opportunities for community events - Loosening the inner areas
Co-benefits and challenges foreseen	01| Climate issues 01-2 Climate adaptation 04| Biodiversity and urban space 04-1 Biodiversity 05| Soil management 05-1 Soil management and quality	- Mitigating the local climate extreme episodes - Participating to spaces connectivity - Contributing to keep organic soil in the city
Possible negative effects	10| People security 06| Resource Efficiency	- Presence of undesired behaviour - Vandalism - Extra water needed for irrigation

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	District / Neighbourhood / Objects
Impacted scales	Neighbourhood / District / City
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	6-47 years => linked with the growth of plants, especially tall trees
Life time	Not defined. It will depend on the maintenance of NBS and the evolve of the population in the Neighbourhood in which will be implanted

Sustainability and Life Cycle	It requires a low to high intensity garden maintenance (more in areas of intensive usage), except for community gardens that need continuous supervision and maintenance. The level of maintenance depends on the climate and type of usage.
Management aspects (kind of interventions + intensity)	Average gardening management.

II.3 Stakeholders involved

Technical stakeholders	- Managers of different institutions - Municipality agency decision-makers - Green spaces management firms, horticulturist and gardeners - Landscape architects and horticulturist
Stakeholders involved in the decision process	- Owners, co-owners - Managers - Municipality - NGOs - Local authorities in charge of the management
Social aspects	- Involvement of the local residents in decision-making - Openness to locals' recommendation - Co-creation processes should be included. - This kind of NBS should be directly linked to awareness and educational activities. - This kind of NBS should be directly linked to activities to improve mental and physical health (wellbeing).

II.4 Design / techniques/ strategy

Knowledge and how-know involved Or key points for success	-General horticultural knowledge - Adaptation to the usage - Regular maintenance and monitoring of usage - Establishment of Management system
Materials involved	Plants - Soil/substrate - Irrigation materials - Fertiliser - Other

II.5 Legal aspects related

- General municipal urban planning processes.
- Local regulations
- Green spaces maintenance regulations (e.g. plant-health products)

II.6 Funding Economical aspects

Range of cost	Investment: €50-500 / square metre Maintenance: €5-20 / square metre annually Irrigation
Origin of the funds (public, private, public-private, other)	- Depending of the owner - Private or public or both

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Solar panels
- Permeable pavement
- Sustainable Irrigation systems
- Natural Wastewater treatment systems
- Blue infrastructures
- Green (cycle & pedestrian) paths or routes.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Willingness of the property owners / institution managers. - Management system and appropriate maintenance. - Acceptance of citizens.
Limiting factors	- Regulatory framework - Vandalism - Institutional constraints - Limitations of accessibility - Failures in maintenance, neglecting
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Concrete pavement Brownfield areas Construction sites Car parking lots Conventional parks
Close NBS	Heritage Gardens Cemetery Large urban public parks Botanical Gardens Private Gardens Urban Farm Rain gardens

IV/ References

IV.1 Scientific and more operational references (presented jointly)

IV.2 Sources used in this factsheet

Carr, S. et al. (1992) Public Space. Cambridge (UK): Cambridge University Press
Low, S. et al. (2005) Public Space & Cultural Diversity. Austin: The University of Texas Press
Kocsis, JB. – Dúll, A. (2017) High Street Repositioning. Manuscript
Konrád, G. – Szelényi, I. (1969) Az új lakótelepek szociológiai problémái. Budapest: Akadémiai Kiadó, quoted by Kocsis-Dúll, 2017.

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Emőke Kósa	**MUTK**	**Writer**
Raúl Sánchez	**CARTIF**	**reviewer**
María González	**CARTIF**	**reviewer**

> On the ground > Structures characterized by food and resources production

> **URBAN FOREST**

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Urban forest is defined as all publicly and privately owned trees within an urban area. This term includes individual trees along streets and in backyards, as well as stands of remnant forest (Nowak et al. 2010). Urban forests are an integral part of urban ecosystems, which includes different elements (people, animals, buildings, infrastructure, water and air) that interact to significantly affect the quality of urban life. The definition of "urban land" must be included into the urban forest definition. The term "urban" connotes areas with relatively high amounts of people and artificial surfaces. And the term "urban land" will be used to define the different kinds of urban forest, depending on the scale and location (Nowak, 2010).

Different variants existing

There are many urban forest classifications,.

It is possible to consider a simple classification of Urban forest based on their location. This classification only considers the city scale:

1) Urban Forests (forests in the urban areas);
2) Peri-urban Forests (forests in the border area of the city);
3) Transitional Forests (forests in the transition area between urban and rural spaces).

Nonetheless this classification does not take into account other relevant aspects of the urban forest, for instance its functionality and management systems. Due to this, an integral classification which includes several and different urbanization variables (location, function and management objectives) (Lee, D-K. 2009) besides of tree species must be considered:

1) Road Forest. Includes trees along railroads, highways, boulevards, roads and streets for protecting, guiding the traffic and improving the environment.
2) Attached Forest. Trees next to schools yards, campuses, hospitals, commercial and business districts, city centres, industrial areas and residential areas to offer entertainment spaces and to improve the quality of life.
3) Landscape and relaxation Forest. Includes trees in the public parks, forest parks, historic cities and scenic zones for landscape and relaxation purposes.
4) Ecological and welfare Forest. Trees are planted as windbreaks in order to avoid soil erosion, floods, to protect watersheds and to reduce noises and pollution.
5) Production and management Forest. Involved trees in the nurseries, orchards, plantation and wood-lands for purchase objectives.

Tree species and their botanical properties are two other parameters to take into account. The tree species installed will depend on the location, climate and specific phenology of each place.

=> Road Forest. Includes trees along railroads, highways, boulevards, roads and streets for protecting, guiding the traffic and improving the environment. This kind of arboreal structure aims to create a natural surrounding around roads, reducing the acoustic/noise pollution, avoiding CO_2 effects from the traffic and improving the air quality. Furthermore, the road forests usually generate a lineal structure of natural ecosystems in cities, which contributes to maintain and improve the biodiversity.

Photo: Road Forest. Source: http://www.treeconomics.co.uk

=> Attached Forest

Trees next to schools yards, campuses, hospitals, commercial and business districts, city centres, industrial areas and residential areas to offer entertainment spaces and to improve the quality of life. These urban forests are intentionally installed next to specific building in order to improve the quality of life of special groups of people (children, students, people in hospital) and to improve the commercial and touristic activities in cities.

Photo: Hospital Río Hortega Valladolid. Source: https://www.consalud.es/c-medico-de-referencia/hospital-universitario-rio-hortega_23654_102.html

Source: Hospital Río Hortega Valladolid Source: http://www.luisvallejo.com/index.php/projects/hospita-universitario-rio-ortega/

Hospital Río Hortega Valladolid
Source: https://www.arquitectes.cat/iframes/paisatge/cat/mostrar_projecte.php?id_projecte=6147&lan=en

=> Landscape and relaxation Forest
Includes trees in the public parks, forest parks, historic cities and scenic zones for landscape and relaxation purposes. These urban forests are mainly aimed to generate a special wellbeing climate areas in cities where citizens can enjoy their leisure time in natural spaces (observing the landscape, walking, doing sports, etc.) improving their physical and mental health. This kind of forest is directly related to the urban biodiversity.


Source: The Mersey Forest - Source: The Mersey Forest.


Physical health improvement. Source: The Mersey Forest.


Walking activity in The UK - Source: The Mersey Forest.

⇨ **Ecological and welfare Forest.**
The aim of these forests is to preserve and restore urban ecosystems and their specific ecosystem services. Trees can work as a barrier in order to avoid the erosion and the noise pollution. These forests can create a new ecological structure which contributes to improve the welfare through plants, soils and biodiversity, all of them installed following coherence criteria.


Lineal urban forest - Source: https://treesforcities.org/


Soil protection by tree roots. Source: http://www.arborilogical.com

⇨ **Production and management forest.**
These forests include all those activities linked to plants/forest business (tree farms, nurseries, orchards, allotment, etc.). In the same way, this forest creates new green job and economic opportunities related to its maintenance and related to land and wood business activities.


Community activities of urban forest management. Source: The Mersey Forest.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues >01-1Climate mitigation >01-2Climate adaptation 02| Urban water management and quality >02-1 Urban water management and quality >02-2 Flood management 03| Air quality >03-1 Air quality at district/city scale <03-2 Air quality at local scale 04| Biodiversity and urban space >03-1 Biodiversity >03-2 Urban space development and regeneration 05| Soil management >05-1 Soil management and quality 07| Public Health and wellbeing >07-1 Acoustic >07-2 Quality of Life >07-3 Health 09| Urban planning and governance >09-1 Urban planning and form	- Sequestering atmospheric carbon dioxide - Reducing the temperature and regulating the microclimate at the object scale (heat stress mitigation) by evapotranspiration and shading - Increasing water infiltration, reducing runoff water volume, increasing of evapotranspiration volume - Minimizing floods effects. - Improve air quality: Pollutants and dust trapping - Providing habitat for several species, promoting biodiversity - Improve the connectivity among green areas - Reducing the erosion caused by water run-off, wind speed (losing soil matter), Increase in soil organic matter - Aesthetic value, cognitive development, improvement of opportunities for exploration by children (reconnecting children with nature) - Increasing physical activity, well-being, and improving/supporting health, moderating stress - Limiting urban sprawl in the case of green belt
Co-benefits and challenges foreseen	06| Resource efficiency >06-1 Food, energy, water >06-2 Raw materials 08| Justice and social cohesion >08-2 Social cohesion 11| Green economy >11-2 Bioeconomy activities >11-3 Direct economic value of NBS	- Providing wood for construction or energy - Contact with nature - Support for education - Value of wood, employment for wood exploitation
Possible negative effects	07| Public Health and well-being 10| People security	- Presence of undesired insects and pests - Promotion of allergies - Dark places to hide - Risk of hitting and damage assets of even people during strong wind events

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Urban forest could be implemented at 3 levels in an urban scale: – Street level – Neighbourhood/district level – City level Occasionally this NBS can be implemented at peri-urban scale.

Impacted scales	The impacted scales will depend on the size/dimension of the urban forest installed. A small urban forest (street trees or simple lines of trees) has a limited impact, mainly above street and neighbourhood and individual buildings (school, hospital, etc). Nonetheless, the impacted scale has a larger scope, because of the synergies among an urban forest and the rest of green spaces in the city. Due to that, it is possible to consider that an urban forest impacts the whole city, thus meaning a city scale impact.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	5-10 years => linked with the growth of plants. It will directly depend on the species and its growth properties. The water/irrigation availability, soil conditions, maintenance, pest, etc. will be other parameters involved in this issue.
Life time	This parameter mainly depends on the followings aspect: - Life period of species. - Adaptation capabilities of the species (it is directly related to the species). - Soils quality and conditions. - Maintenance and care activities. - Water / irrigation availability - Pests. The gradual replacement of the urban forest will be possible by renovating each individual sick or dead tree. In this way, it will be possible to maintain a healthy urban forest for a long time.
Sustainability and life cycle	Urban forest is “per se” a sustainable element. To ensure that, it will be necessary to design the urban forest taking into account that it should need almost no maintenance. This will be possible using native species, specific water requirement species, high adaptation capacity species and frugal species. Likewise, trees and their derived by-products can be used as biomass, compostable elements, wood building material, etc.
Management aspects (kind of interventions + intensity)	- Depending on the local weather, a plantation watering will be necessary. The water requirements will decrease over the years (until a specific level). - Occasionally, depending on the species, it will be necessary to apply pruning or cleaning treatments. It allows a right development of trees. - Occasionally, it will be necessary to apply treatments to fight against pests and weeds.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Local authorities. - Natural Resources Management entities. - The Citizenship. - NGOs and other communal entities. - Land owners, land co-owners (in case of a joint ownership property). - Tenants.
Technical stakeholders & networks	- Forestry engineers, Agricultural engineers - Architects and town planners. - Landscape designer. - Specialized green spaces management companies, horticulturist and gardeners. - The technical stakeholder’s network for this kind of NBS is well identified.
Social aspects	- It will be necessary a deep study about the acceptation of this NBS. - It will be necessary a wide information campaign. - It will be necessary to associate this NBS with activities related to social cohesion, local job creation, promotion of mental and physical health in these spaces, educational activities, etc. - It will be very important to implement co-creation processes linked to this NBS (participatory process).

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Municipality and local authorities' involvement. - Base-line of the city. - Forestry-agronomic features of place to be used. - Urban landscape criteria. - Selection and design of the plantation (plantation framework, methodology, adapted species, etc) - Selection of tree species adapted to: • Local climate. • Spaces selected. • Social necessities. • Challenges targeted. - Development of a monitoring program as a strategy to measure impacts of the NBS. - Establishment of a maintenance program. - Establishment of by-products reuse program.
Materials involved	- Vegetable species (trees, bush and shrub species). - Soils and substrates. - Watering/irrigation material. - Fertiliser - Specific supports will be necessary for trees/plants that need to be guided

II.5 Legal aspects related

It will be necessary to take into account the national and local regulation related to forest installation and regulatory framework regarding the use of seeds and native species. In the same way, it will be necessary to consider the legal aspects linked to urban requirements (accesses, emergency entries, etc.).

II.6 Funding Economical aspects

Range of cost	It is important to remark that the cost of this NBS depends on many factors, all of them being really uncertain, since their market price strongly varies with the season, the city, and the country,. The final cost will be related to the following parameters (McPherson et al. 2005): - Implantation of plants (plants and tree pits installation) - Management cost. It includes planting, pruning, irrigation, insect and disease control, tree removal, tree residue from pruning and removal and fire protection. - Program administration - Infrastructure repair - Liability and litigation processes.
Origin of the funds (public, private, public-private, other)	Usually, funds come from municipalities, since they are in charge of the administration and management of the green spaces in cities as local authorities. Nevertheless and occasionally the management of urban forests is carried out by other kind of entities (NGOs) which have different funding ways.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Urban forest can be combined with many different NBS:

- Large public parks
- Wood
- Street trees
- Urban orchard

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Specific species (trees, shrub and bush) - The right place. - Soil quality - Cover water necessities. - Management plan (design, planting, pruning, irrigation, insect and disease control, tree removal, tree residue from pruning and removal and fire protection) - Social acceptance
Limiting factors	- Specific species (trees, shrub and bush). - The right place. - Soil quality - Water necessities. - Difficulties of management - Social non-acceptance - Governance and authorizations - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- It does not apply.
Close NBS	- Green paths, routes and cycle ways. - Shade trees - Cooling trees. - Urban forest as carbon sink. - SUDs (Sustainable Urban Drainage) - Hard drainage systems (flood prevention) - Re-naturing parking - Rain gardens - Floodable park - Urban Green filter - Natural wastewater treatment plants. - Green noise barriers. - Green roof. - Urban orchard - Pollinator verges - Mobile gardens - Smart soils. - Natural pollinator's modules - Green fences - Fruit forest - Bio-boulevards. - Urban farming activities. - Wood allotments - Forest school. - Forest church. - GI for Physical and mental health.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Lee, Dong-Kun, Classification of Urban Forest Types and its Application Methods for Forests Creation and Management. Research Institute for Agriculture and Science, Seoul National University, 2009.

McPherson, E.G. et al. 2005. Municipal Forest Benefits and Costs in Five Cities. Journal of Forestry. December (2005): 411-416.

David J. Nowak, Susan M. Stein, Paula B. Randler, Eric J. Greenfifield, Sara J. Comas, Mary A. Carr, and Ralph J. Alig. "Sustaining America's Urban Trees and Forests". United States Department of Agriculture. Forest Service. General Technical Report NRS-62 June 2010..

IV.2 Sources used in this factsheet

Blood, A. et al. "How Do Urban Forests Compare? Tree Diversity in Urban and Periurban Forests of the Southeastern US". 2016

Hostnik, R. "The Context of Urban Forests and the Development of Urban Forestry in Highly Forested EU Country: the Experience of Celje, Slovenia" Slovenia Forest Service, Unit Celje, Ljubljanska .

Liu C F, Li X M, 2012. "Carbon storage and sequestration by urban forests in Shenyang, China". Urban Forestry & Urban Greening, 11(2): 121–128. doi: 10.1016/j.ufug.2011.03.002

Sanda, L., 2015, *Weather in the city – How design shapes the urban climate*, naio10 publishers, 224 pages. FASSADEN GRÜN. https://www.fassadengruen.de/eng/indexeng.htm

Urban Forestry Best Management Practices for Public Works Managers: URBAN FOREST MANAGEMENT PLAN. Series Research and Education Steering Committee. Your State Urban Forestry Coordinator. www.arborday.org/programs/urbanforesters.cfm

Urban GreenUP project "**New Methodology to Re-naturing Cities through Nature-Based Solutions (NBS)".** This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730426.

http://www.merseyforest.org.uk/

http://www.treeconomics.co.uk

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Marjorie Musy	Cerema	Reviewer

➢ On the ground

➢ Structures associated to urban networks

> GREEN TRAM TRACK

> STREET TREE

> GREEN STRIP

> GREEN WATERFRONT

> GREEN PARKING LOT

> UNSEALED PARKING LOT

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	This NBS Type is about green tram tracks which are unsealed and greened with grasses or sedum species and thus achieve several valuable ecological, economic and urban design benefits.

Different variants existing

Two kinds can be distinguished, depending on the chosen community of plants:

=> Grass tram track

The grass tram track consists mostly of grasses and partially herbs, which have typical more than 15 cm substrate depth and following a high water and maintenance demand. The advantages are the high resilience for utilisation and the whole application area from sunny to shady conditions.

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=> Sedum tram track

By a sedum tram track mainly Sedum species and partially herbs are used, which need a substrate depth from typically 4-8 cm. Compared to grasses, the applied plants have a lower water and maintenance demand and following a higher resilience for drought. It's not suitable for shady conditions but have a more valuable ecological benefit than grass tram track.

Sedum track Berlin
© Schreiter (2010)

Sedum track Berlin
© Schreiter (2010)

Sedum track Berlin
© Schreiter (2010)

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality 02-1 Urban water management 07| Public Health and wellbeing 07-1 Acoustic 07-2 Quality of Life	- Reduction of runoff water volumes, evapotranspiration - Aesthetic value - Noise/Acoustic buffer
Co-benefits and challenges foreseen	01| Climate issues > 01-2 Climate adaptation 02| Water management and quality 02-1 flood management 04| Biodiversity and urban space 04-1 Biodiversity 09| Urban planning and governance 09-1 Urban planning and form	- Temperature reduction, helps mitigating urban heat island - Water buffer - Provide nutrition sources for birds and insects - Increasing green areas
Possible negative effects	07| Public Health and well-being	- Presence of undesired insects

II/ More detailed information on the NBS types

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Neighbourhood City
Impacted scales	Depending on the scales the actions can have wide-ranging impacts, reaching from the close neighbourhood to a throughout connected greened city track.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Immediately to 1-2 years, depending on the chosen seeding method. Usually, pre-cultivated turf or sedum are applied, which bring the full effect promptly.
Life time	By appropriate maintenance and conditions very persistent and basically self-adjusting – like lawns or extensive green roofs and have a longer life-time like the rails.
Sustainability and life cycle	Because of production method the use of turf is controversial discussed. By sedum track the substrate can be recycling material.
Management aspects (kind of interventions + intensity)	- Perhaps irrigation (only at extremely hot and dry periods) - Perhaps mowing (grass tram tracks)
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality departments - traffic enterprise
Technical stakeholders & networks	- construction engineer - Landscape architects - Perhaps maintenance company, horticulturist and gardeners. - The technical stakeholders network varies from cities and countries.
Social aspects	- Tram tracks are anyhow a common and necessary urban infrastructure. Additional greening can be a selling point for the acceptance of a route by citizens.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition • challenges targeted - Selection of substrate
Materials involved	- track systems - drainage material - substrate - turf and/or seeding/sprouts  Grass © Green4Cities  Sedum © Green4Cities

II.5 Legal aspects related

In Germany the acceptance of a route is a requirement to get the approval from authorities, wherefore greened tracks are target-aimed. Further information's are not available.

II.6 Funding Economical aspects

Range of cost	Actually, collecting general information about the costs for this NBS Type is quite difficult, due to different approaches, construction types and vegetation technics. Further traffic enterprises are often positioned in different ways by differences in placing of construction and maintenance tasks. Therefore credible figures concerning costs for green tram tracks installation and maintenance cannot be taken.
Origin of the funds (public, private, public-private, other)	- nA

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

nA

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- site-specific adapted mixture of plant species - ensured maintenance
Limiting factors	- high(er) construction costs - regular maintenance costs
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Concrete track These other solutions target one or several challenges completed by this NBS, sometimes more efficiently, but none of them touches such a diversity of challenges. Moreover, solutions proposed are often more expansive. These solutions propose other aesthetics for the building.
Close NBS	• Flower fields • Lawns • Green strips • Unsealed car parks • Planted car parks • Extensive green roof This NBS Type is tailor-made for a specific application case by the hybrid-function of a green space by same time being an infrastructure for public transport. Nevertheless, NBS Types which use grasses or herbs on the ground and are designed for temporarily use have similar effects and needs.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

KAPPIS Christel, SCHREITER Hendrikje, REICHENBACHER Karsten (2015): Green track – progress report and overview – A contribution to the green track network. Infrastruktur & Bau, Grünes Gleis. Eurailpress. Online: http://www.gleiswerkstatt.de/portfolio/artikel-gruenes-gleis.pdf

KAPPIS Christel, SCHREITER Hendrikje (2016): Handbook track greening – Design, Implementation, Maintenance. Grüngleisnetzwerk. Berlin.

SCHREITER Hendrikje (2010): Green Tram Tracks – The advantages of implementing vegetation systems in tram tracks. Institute for Agricultural and Urban Projects at the Humboldt-University, Berlin. Prague. Online: http://www.urbantrack.eu/images/site/publications/FinalConference/presentations/07_ASP_Grassed%20Track.pdf

SCHREITER Hendrikje, KAPPIS Christel (2013): Green Tram Tracks – Effect & Functions – Review and own research. Institute for Agricultural and Urban Projects at the Humboldt-University, Berlin. WGIC Nantes. Online: http://www.iasp.asp-berlin.de/Poster/poster1301.pdf

SCHREITER Hendrikje, KAPPIS Christel (nA): Effect and Function of Green Tracks. Grüngleisnetzwerk. Berlin. Online: http://www.gruengleisnetzwerk.de/images/downloads/effects.pdf

WEISS Christa (2016): Begrünte Bahntrassen – Mehr Grün im Gleis. Freiraumgestalter 03/2016. Online: https://www.torial.com/christa.weiss/portfolio/178112

IV.2 Sources used in this factsheet

Green4Cities – www.green4cities.com

SCHREITER Hendrikje (2010): Green Tram Tracks – The advantages of implementing vegetation systems in tram tracks. Institute for Agricultural and Urban Projects at the Humboldt-University, Berlin. Prague. Online: http://www.urbantrack.eu/images/site/publications/FinalConference/presentations/07_ASP_Grassed%20Track.pdf

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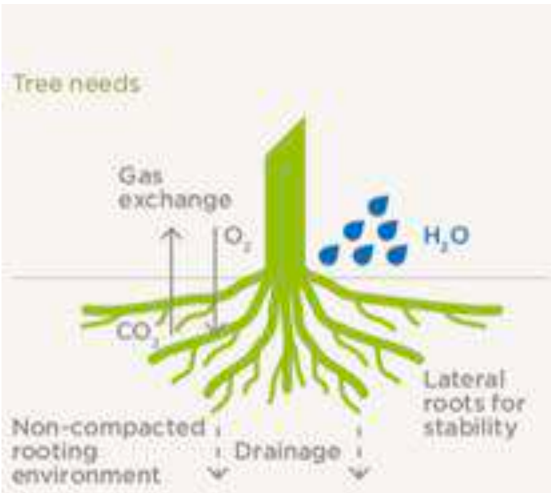
Barnabás Körmöndi	MUTK	Reviewer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing	
Definition	"The best time to plant a tree was 20 years ago. The second best time is now, says a wise Chinese proverb. " A street tree is any tree growing within the public-right-of-way and is thus managed by the city. Typically, they are located along sidewalks and/or streets. This NBS type is one of the most important part in the urban green network. This effective and important implementation has multiple visual and physical impacts on quality of life in urban areas. They provide shading and cooling through transpiration and evapotranspiration and thus reduce temperature. Compared to a single tree, street trees are planted in groups like a canopy road/avenue/boulevard. Trees need water and oxygen to survive and be productive, thus the water-oxygen-balance is of high importance for a successful tree growing. Street trees have e.g. lower water use compared to single trees, because there are not that exposed. But the requirements for street trees within the urban space are often limited available.  Fig. Tree needs (TDAG, 2014)

Different variants existing

Two kinds can be distinguished, depending on the construction form:

=> non-paved tree pit

This sub-type is characterized by an open, non-paved surface of the tree pit.

non-paved street trees
© Green4Cities

non-paved street trees
© Green4Cities

=> paved tree pit

In contrast, this sub-type is defined by a paved surrounding surface and built-over of the tree pit.

paved street trees
© Green4Cities

paved street trees
© Green4Cities

paved street trees
© Green4Cities

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues 01-1Climate mitigation 01-2Climate adaptation 03| Air quality 03-1 Air quality at district/city scale 03-2 Air quality at local scale 04| Biodiversity and urban space 04-1 Biodiversity 06| Resource efficiency 06-1 Food energy and water 07| Public Health and wellbeing 07-2 Quality of Life 09| Urban planning and governance 09-1 Urban planning and form	- Carbon sequestration and Insulating effects. - Reducing the temperature and regulating the microclimate at the object scale (heat stress mitigation) by evapotranspiration and shading - dry deposition of air pollutants, help filter air pollutants - providing habitat for several species, promoting biodiversity - provide shading for buildings - aesthetic value, cognitive development - Increasing green areas and improve the connectivity among green areas
Co-benefits and challenges foreseen	02| Urban water management and quality 02-2 Flood management 05| Soil management 05-1 Soil management and quality 08| Justice and social cohesion 08-2 Social cohesion	- Interception of stormwater - Reduction of erosion due to water run-off, improve the soils biodiversity - Raw material provision facilitating social interaction and community attachment, interaction among neighbours, promoting social cohesion

Possible negative effects	03| Air quality 07| Public Health and well-being 10| People security	- A too dense canopy can trap pollutants in the street - Presence of undesired insects and pests - Promotion of allergies - Dark places to hide

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Along streets and sidewalks Ranging from a small group of trees to a long canopy road/alley/avenue.
Impacted scales	Linked with the scale of implementation. A long structure of street trees can have a wide-ranging effect to the neighbourhood and whole city, beside the effects on the plot scale. A narrow implementation of street trees has less impacts.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Full effect is linked with the plant size, which is further linked with the tree pit size and specific conditions as well as maintenance – thus a very complex fabric. E.g. if a large tree is planted, the full effect can be reached very soon respectively immediately. A small and young tree need 5-10 years to get bigger. Due to harsh conditions, the growing rate for street trees is lower compared to conditions in forests.
Life time	It depends strongly on conditions, maintenance and plant species: - Street trees typically do not reach the natural age of common trees, because of the exposed and hard conditions in urban areas beside roads. - Average lifespan for a street tree has lowered in the last years dramatically to 7-15 years (COST Action 12, 2005)
Sustainability and life cycle	Trees can be composted and substrate can be basically recycled. Tree props are commonly out of wood.
Management aspects (kind of interventions + intensity)	- irrigation - cutting - pruning - nutrients - perhaps soil improvement - perhaps tree pit maintenance - 1-20 interventions per year (depending on age and precipitation)
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipalities – different departments (green, roads, ...)
Technical stakeholders & networks	- Landscape architects - Specialized green spaces management firms, horticulturist and gardeners, often city department. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- Necessity to find an agreement with public regarding tree planting.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • climate change (drought) • acrid salts • challenges targeted • the traffic intensity (the level of air pollution) - Root management - Irrigation - adequate substrate volume - Drainage - Aeration - Maintenance - Plant quality: High quality of stem, crown, roots - Careful transportation - Clearance gauge/diagram (traffic safety) - tree prop - planting height (stem over substrat) - perhaps ram protection
Materials involved	- trees - substrate/soil - drainage layer - tree prop (mostly wooden) - perhaps tree pit - perhaps mulch layer - perhaps irrigation system - perhaps root barrier - perhaps ram protection

II.5 Legal aspects related

Some cities have a strict tree protection law – basically every tree is protected and are subject to permit (private and public with basic criteria's).

II.6 Funding Economical aspects

Range of cost	Investment: 200-1500€ / pcs. and much more (depending on size and specific conditions) Maintenance: 25-60 € / pcs. One of the most efficient NBS related to cost/benefit.
Origin of the funds (public, private, public-private, other)	- Basically no funds because this type is typically in the range of the city. - Perhaps sometimes kind of private sponsorship.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with structural soils

To avoid road and pathway damages, the use of structural soil is a proved and effective approach.

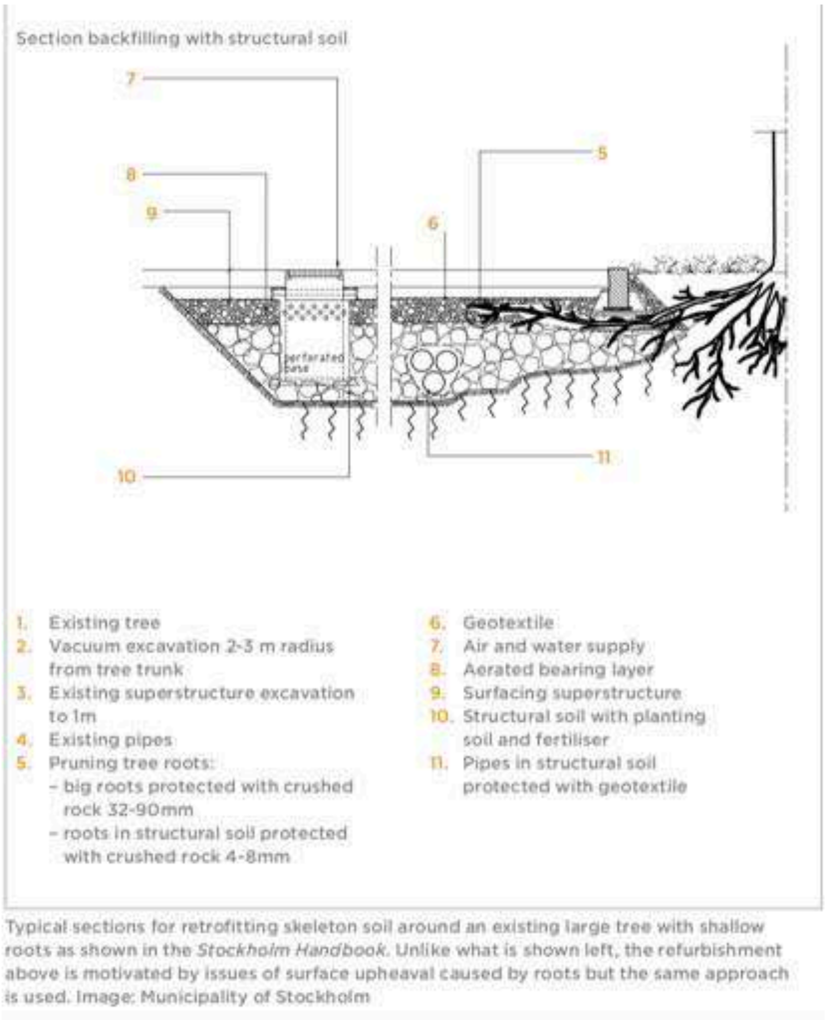


Fig. Typical sections for retrofitting skeleton soil around an existing large tree with shallow roots as shown in the Stockholm Handbook. Unlike what is shown left, the refurbishment above is motivated by issues of surface upheaval caused by roots but the same approach is used. Image: Municipality of Stockholm (TDAG, 2014)

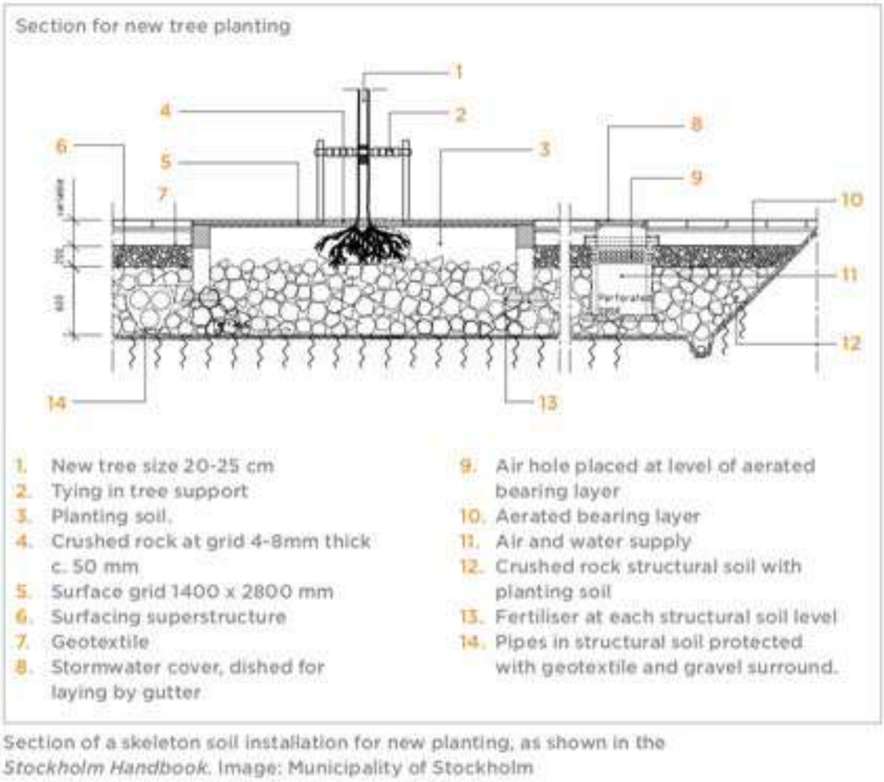


Fig. Section of a skeleton soil installation for new planting, as shown in the Stockholm Handbook. Image: Municipality of Stockholm (TDAG, 2014)

- Combination with rain gardens

Actual trend is to use planted areas to reduce storm water runoff and improve rainwater management by maximum retention of water and thus gain a load relief for sewerage. Specific substrates are improving the infiltration properties of tree pits.

Draingarden © Zenebio

- Combination with urban gardening

Tree pits can be additionally used for urban gardening. Pioneer projects, e.g. in Vienna, have shown the successful combination of this solutions.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Quality of Soil and drainage construction and adequate volume - The right tree species at the right place
Limiting factors	- Difficulties of adequate construction - Difficulties in adequate management - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Shading structure Shading structure also gain the effect of shading, but this conventional solution is compared to trees, not living and thus have less benefits.
Close NBS	• Single trees • Woods • Urban forest Similar types are also based on trees and have similar effect, even more in their environment/surrounding/composition then exposed street trees which are typically along streets.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

AARP (2014): Street trees – a livability fact sheet. WALC Institute. https://www.mayorsinnovation.org/images/uploads/pdf/10d-AARP-Livability-FactSheet-Street-Trees-82514.pdf

COST Action E12 (2005): Urban forests and trees. Technical Annex. Online: http://www.urbano-zelenilo.org/wp-content/uploads/COST_E12_Urban_forests_and_trees.pdf

EPA (2013): Stormwater to street trees. Engineering Urban forests for stormwater management. Online: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

FLL (2015): Teil 1: Planung, Pflanzarbeiten, Pflege

FLL (2010): Teil 2: Standortvorbereitungen für Neupflanzungen; Pflanzgruben und Wurzelraumerweiterungen, Bauweisen und Substrate.

GALK (2018): Straßenbaumliste. GartenAmtsLeiter-Konferenz. Online: http://www.galk.de/arbeitskreise/ak_stadtbaeume/webprojekte/sbliste/

GOODWIN, D. (2017): The urban tree. Routledge.

HVASS, N (2008): European Tree Planting Guide – with focus on urban trees in the temperate zone

LI, Y. Y. et al. (2011): Key street tree species selection in urban areas

PAULEIT, S. (2002): Tree establishment practice in towns and cities – results from european survey

TDAG (2014): Trees in hard landscapes – a guide for delivery. Tree design action group. Online: http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-hard-landscapes_september_2014_colour.pdf

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Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	Green or vegetated strips are greened surfaces next to impermeable surface, typically beside roads and railways. They are typically covered with grasses, shrubs and/or small trees. Due to road safety they have to be cut regularly (MARTÍNEZ 2016).

Construction

Green strips are basically composing out of three main elements (MARTÍNEZ 2016):

=> Vegetation

The typical vegetation of green strips are grasses and sometimes little shrubs and/or small trees. Main function of this layer is to protect soil erosion.

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=> Topsoil

Topsoil is the growing substrate layer, where the vegetation is planted, typically with a depth of at least 150 mm.

=> Engineered soil

The last layer is a kind of drainage layer which is composed out of different grain sizes. The construction should have at least a depth of 300 mm.

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Water management and quality 02-1 Urban water management 03| Air quality 03-1 Air quality at district/city scale 03-2 Air quality at local scale 04| Biodiversity and urban space 04-1 Biodiversity 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 07| Public Health and wellbeing 07-2 Quality of Life	- Reduction of runoff water volumes (). - Air pollutants reduction (dry deposition) - Provide a habitat for birds and insects - Increasing and preserving biodiversity - Improve the connectivity among green areas - Reduction of erosion due to water run-off -Aesthetic value

Co-benefits and challenges foreseen	01| Climate issues 01-1 Climate mitigation 01-2 Climate adaptation 02| Water management and quality 02-2 Flood management	- Carbon storage -Contribute to carbon storage - Contribute to heat island reduction - Increasing water infiltration
Possible negative effects	07| Public Health and well-being	- Presence of undesired insects and pests - Promotion of allergies

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Along roads and pathways.
Impacted scales	Depending on the scale of implementation, broad and long green strips can have impacts from neighbourhood to city scale, compared to short and thin ones which are mostly limited to the building plot.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Depending on the chosen planting. Seeds need to germinate and grow compared seedlings or pot plants of perennials; up to 1 year. Full effect of shrubs and trees is linked with the plant size, which is further linked with the substrate depth and specific conditions as well as maintenance – thus a very complex fabric. E.g. if a large tree is planted, the full effect can be reached very soon respectively immediately. A small and young tree need 5-10 years to get bigger. Due to harsh conditions, the growing rate for street trees is lower compared to conditions in forests.
Life time	By the use of a balanced mix of persistent plant species, they are usually self-sustaining. But it is also common to change planting design in terms of aesthetic regularly and seasonal.
Sustainability and life cycle	Plants can be composed and soil/substrate, if improved, can be recycled.
Management aspects (kind of interventions + intensity)	- limited irrigation - nutrients - pruning - perhaps mowing - 1-x interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality departments (green space, roads, ...) - eventually citizens through civic activism for urban gardening
Technical stakeholders & networks	- Landscape architects - Specialized green spaces management firms, horticulturist and gardeners, often city intern departments. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- by civic activism => importance of the participatory process.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • exposition • climate change (droughts) • acrid salts • challenges targeted • the traffic intensity (the level of pollution) - Gardener skills - Set up the maintenance
Materials involved	- plants: shrubs, herbs, grasses - substrate/soil

II.5 Legal aspects related

nA

II.6 Funding Economical aspects

Range of cost	Investment: 10-70 €/m² (inclusive trees) Maintenance: 1-2,5 €/ m² /a (GALK, 2012) Possible cost savings in management and maintenance due to less mowing frequencies.
Origin of the funds (public, private, public-private, other)	- Basically no funds because this type is typically in the range of the city. - Perhaps sometimes kind of private sponsorship programs.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with rain gardens

Actual trend is to use planted rain gardens beside roads to reduce storm water runoff and improve rainwater management by maximum retention of water and thus gain a load relief for sewerage. Specific substrates are improving the infiltration properties of tree pits.

Draingarden © Zenebio

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Substrate/soil quality and volume - The right plant choice (resistant species)
Limiting factors	- Adequate maintenance - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• sealed surface Cannot keep pace with greened version, exception for transportation use.
Close NBS	• Flower fields • Lawns • Grass tram tracks • Meadow Green strips have a big potential for high biodiversity purpose through diverse plant mixture/selection.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

GALK (2012): Kennzahlen für die Erstellung und Unterhaltung von Grünanlagen. Online: http://www.galk.de/arbeitskreise/ak_orga_betriebswirt/down/kennzahlen_eschenbruch_120529.pdf

MARTÍNEZ Carlos Hidalgo (2016): Infrastructure asset management for nature-based solutions (NBS): a guidance for collecting asset information and data for NBS maintenance management Application at Trondheim district (Norway). Norwegian University of Science and Technology. Online: https://brage.bibsys.no/xmlui/bitstream/handle/11250/2415580/15825_FULLTEXT.pdf?sequence=1

LBAP (nA): Roadside verges. Local Biodiversity Action Plan. Online: http://www.cheshirewildlifetrust.org.uk/sites/default/files/files/Roadside%20verges.pdf

SULLIVAN O. (2017): Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management. Online: http://www.cheshirewildlifetrust.org.uk/sites/default/files/files/Roadside%20verges.pdf

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I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	Green or vegetated strips are greened surfaces next to impermeable surface, typically beside roads and railways. They are typically covered with grasses, shrubs and/or small trees. Due to road safety they have to be cut regularly (MARTÍNEZ 2016).

Construction

Green strips are basically composing out of three main elements (MARTÍNEZ 2016):

=> Vegetation

The typical vegetation of green strips are grasses and sometimes little shrubs and/or small trees. Main function of this layer is to protect soil erosion.

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=> Topsoil

Topsoil is the growing substrate layer, where the vegetation is planted, typically with a depth of at least 150 mm.

=> Engineered soil

The last layer is a kind of drainage layer which is composed out of different grain sizes. The construction should have at least a depth of 300 mm.

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Water management and quality 02-1 Urban water management 03| Air quality 03-1 Air quality at district/city scale 03-2 Air quality at local scale 04| Biodiversity and urban space 04-1 Biodiversity 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 07| Public Health and wellbeing 07-2 Quality of Life	- Reduction of runoff water volumes (). - Air pollutants reduction (dry deposition) - Provide a habitat for birds and insects - Increasing and preserving biodiversity - Improve the connectivity among green areas - Reduction of erosion due to water run-off -Aesthetic value

Co-benefits and challenges foreseen	01| Climate issues 01-1 Climate mitigation 01-2 Climate adaptation 02| Water management and quality 02-2 Flood management	- Carbon storage -Contribute to carbon storage - Contribute to heat island reduction - Increasing water infiltration
Possible negative effects	07| Public Health and well-being	- Presence of undesired insects and pests - Promotion of allergies

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Along roads and pathways.
Impacted scales	Depending on the scale of implementation, broad and long green strips can have impacts from neighbourhood to city scale, compared to short and thin ones which are mostly limited to the building plot.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Depending on the chosen planting. Seeds need to germinate and grow compared seedlings or pot plants of perennials; up to 1 year. Full effect of shrubs and trees is linked with the plant size, which is further linked with the substrate depth and specific conditions as well as maintenance – thus a very complex fabric. E.g. if a large tree is planted, the full effect can be reached very soon respectively immediately. A small and young tree need 5-10 years to get bigger. Due to harsh conditions, the growing rate for street trees is lower compared to conditions in forests.
Life time	By the use of a balanced mix of persistent plant species, they are usually self-sustaining. But it is also common to change planting design in terms of aesthetic regularly and seasonal.
Sustainability and life cycle	Plants can be composed and soil/substrate, if improved, can be recycled.
Management aspects (kind of interventions + intensity)	- limited irrigation - nutrients - pruning - perhaps mowing - 1-x interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality departments (green space, roads, ...) - eventually citizens through civic activism for urban gardening
Technical stakeholders & networks	- Landscape architects - Specialized green spaces management firms, horticulturist and gardeners, often city intern departments. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- by civic activism => importance of the participatory process.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • exposition • climate change (droughts) • acrid salts • challenges targeted • the traffic intensity (the level of pollution) - Gardener skills - Set up the maintenance
Materials involved	- plants: shrubs, herbs, grasses - substrate/soil

II.5 Legal aspects related

nA

II.6 Funding Economical aspects

Range of cost	Investment: 10-70 €/m² (inclusive trees) Maintenance: 1-2,5 €/ m² /a (GALK, 2012) Possible cost savings in management and maintenance due to less mowing frequencies.
Origin of the funds (public, private, public-private, other)	- Basically no funds because this type is typically in the range of the city. - Perhaps sometimes kind of private sponsorship programs.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with rain gardens

Actual trend is to use planted rain gardens beside roads to reduce storm water runoff and improve rainwater management by maximum retention of water and thus gain a load relief for sewerage. Specific substrates are improving the infiltration properties of tree pits.

Draingarden © Zenebio

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Substrate/soil quality and volume - The right plant choice (resistant species)
Limiting factors	- Adequate maintenance - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• sealed surface Cannot keep pace with greened version, exception for transportation use.
Close NBS	• Flower fields • Lawns • Grass tram tracks • Meadow Green strips have a big potential for high biodiversity purpose through diverse plant mixture/selection.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

GALK (2012): Kennzahlen für die Erstellung und Unterhaltung von Grünanlagen. Online: http://www.galk.de/arbeitskreise/ak_orga_betriebswirt/down/kennzahlen_eschenbruch_120529.pdf

MARTÍNEZ Carlos Hidalgo (2016): Infrastructure asset management for nature-based solutions (NBS): a guidance for collecting asset information and data for NBS maintenance management Application at Trondheim district (Norway). Norwegian University of Science and Technology. Online: https://brage.bibsys.no/xmlui/bitstream/handle/11250/2415580/15825_FULLTEXT.pdf?sequence=1

LBAP (nA): Roadside verges. Local Biodiversity Action Plan. Online: http://www.cheshirewildlifetrust.org.uk/sites/default/files/files/Roadside%20verges.pdf

SULLIVAN O. (2017): Optimising UK urban road verge contributions to biodiversity and ecosystem services with cost-effective management. Online: http://www.cheshirewildlifetrust.org.uk/sites/default/files/files/Roadside%20verges.pdf

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> GREEN WATERFRONT

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing	
Definition	Due to climate change sea level is rising and thus brings challenges for local governments with coastal access and communities - waterfronts. Waterfronts are a space, parts or a district of a city with access to water, often grown historically without an overall plan and thus nowadays often revitalised. It is not only about a sea access, it also can be direct access to lakes, rivers or similar larger water elements. Beside sea level rising, extreme weather events are increasing too and thus storm water management is getting a more relevant issue. The implementation of a green waterfront city provides opportunities to restore and protect coastal ecosystems and to protect coastal communities by same time having a wide range of benefits, especially regarding recreation. By the same time, these complex urban processes are often challenged by social challenges like gentrification and need in general an overall strategy.  Fig.: Vancouver waterfront (LMN Architects 2018)
Different variants existing <u>Six kinds can be distinguished, depending on the typologies:</u> **=> New urban expansion** This sub-type is characterized by an overall rebuild of available areas, typically old industrial or port areas.	
=> Waterfront and great events Development based on a greater event, like an Olympia or an Expo – re-use of areas.	
=> Port settlement Settlements around port with harbour.	
=> Reuse of Port areas Former port areas are re-used.	
=> Flood defence Structural interventions for flood defence.	
=> Urban beaches Environment around artificial beach installations.	

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues 01-1 Climate mitigation 01-2 Climate adaptation 02| Water management and quality 02-2 Flood management 04| Biodiversity and urban space 03-1 Biodiversity 03-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 07| Public Health and wellbeing 07-2 Quality of Life 09| Urban planning and governance 09-1 Urban planning and forms	- Carbon sequestration in the green area - Temperature reduction due to a better diffusion of see breeze - Buffer role in case of rise ot the water level - Increasing and preserving biodiversity (habitat) and improve the connectivity between blue, green areas - Increasing green areas - Avoid erosion - Aesthetic value, contact with nature - Limiting built area, increasing green space
Co-benefits and challenges foreseen	02| Water management and quality 02-1 Urban water management 08| Justice and social cohesion 08-2 Social cohesion	- Reduce water run-off - Support for education
Possible negative effects	07| Public Health and well-being 08| Environmental justice and social cohesion 08-2 Social cohesion 10| People security	- Promotion of allergies - Gentrification - Risks due to water access

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Typically district or city scale – because of overall concept
Impacted scales	The impacted scales are wide-ranging from district to whole city.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Depending on scope of actions and area size 2-20 years?
Life time	Depending on action – in general basically renaturation actions and thus self-sustaining.
Sustainability and life cycle	Property prices are often increasing dramatically by waterfronts since post-industrialism.
Management aspects (kind of interventions + intensity)	- Overall master management strategy
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - municipality departments (nature protection, water, ...)
Technical stakeholders & networks	- Landscape architects/Urban planner/cultural technique expert - Specialized green spaces management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is not very well identified.
Social aspects	- Necessity to find an agreement with neighbour and citizens - Gentrification

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of NBS and plants adapted to: • the local climate • challenges targeted
Materials involved	- plants - substrate/soil - drainage - sand

II.5 Legal aspects related
National laws Regional laws/guidelines

II.6 Funding Economical aspects	
Range of cost	nA
Origin of the funds (public, private, public-private, other)	nA

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Nearly every NBS type or action.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Overall strategy plan - Adequate water management - The right plant choice
Limiting factors	- Maintenance - Vandalism

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Grey waterfront No living solution with the basic main function but with less diversity of multiple benefits.
Close NBS	• Related to all NBS Types out of the Water category. The green waterfront city is a combination of several NBS action performing together.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

BABALIS, D. (2017): Waterfront Urban space – Designing for Blue-Green Places. Altralinea edizioni.

DAVIDSON, M. (nA): Urban Geography: Waterfront development. InTech. Online: https://pdfs.semanticscholar.org/9c81/3c787590feb2f932de2df7b2908aeb255793.pdf

HAASE, D et al. (2017): Greening cities e To be socially inclusive? About the alleged paradox of society and ecology in cities.

LMN Architects (2018): How Vancouver greened its waterfront. Online: http://lmnarchitects.com/case-study/vancouver-greened-waterfront?doing_wp_cron=1521814449.0439600944519042968750

TIMUR, U. (2013): Urban Waterfront Regenerations. Online: http://cdn.intechopen.com/pdfs/45422/InTech-Urban_waterfront_regenerations.pdf

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I/ General description and characterization of the NBS types

I.1 Definition and different variants existing

Definition

Greened parking lots is the greened version of a parking plot. Compared to traditional solutions, they use vegetation for storm water management and to address several further urban challenges. Traditional solutions gain the impacts of Urban Heat Islands (UHI), can cause water quality and storm water issues. They are characterized with grass and/or herb plantings.

Fig. Anatomy of a green and sustainable parking lot (MCPC, 2015)

Different variants existing

Two kinds can be distinguished, depending on the construction form:

=> Grass-block Systems

This permeable system is typically composed out of interlocking blocks of concrete, plastic or synthetic nets which have openings for grasses.

 © Green4Cities	 © Green4Cities	 © Green4Cities

=> Gravel turf

This sub-type is perfect for the construction of parking lots with low frequency. The substrate layer can be composed out of recycling materials or gravel in different grain sizes with low organic material. Suitable grasses and herbs are covering the surface by same time allowing water infiltration and evapotranspiration. It can be also used for emergency access.

It can be differentiated further as a one- or a two-layer construction.

One-layer construction

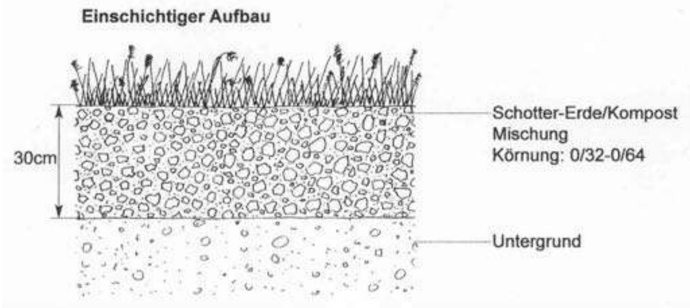

Fig. One-layer construction (EU Green concrete/BOKU)

Two-layer construction

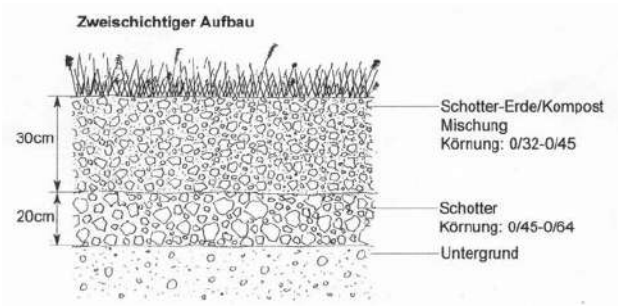

Fig. Two-layer construction (EU Green concrete/BOKU)

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I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues 01-1Climate mitigation 01-2Climate adaptation 02| Urban water management and quality 02-1 Urban water management and quality 02-2 Flood management 04| Biodiversity and urban space 04-1 Biodiversity 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality	- Carbon sequestration - Mitigation of urban heat island - Reduction of runoff water volumes. - Increasing of evapotranspiration volume - Increasing water infiltration. - Minimizing floods effects. - Increasing and preserving biodiversity - Provide a habitat for birds and insects - Improve the connectivity among green areas - Improve the soils biodiversity - Reduction of erosion due to water run-off
Co-benefits and challenges foreseen	07| Public Health and wellbeing 07-1 Acoustic 07-2 Quality of Life	- Noise absorption - Aesthetic value - Contact with nature

Possible negative effects	07| Public Health and well-being	- Presence of undesired insects and pests - Promotion of allergies

II/ More detailed information on the NBS types

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Object/Neighbourhood: Beside streets and sometimes on large areas.
Impacted scales	Depending on the size, but in most cases the impact is limited to the building plot or the close neighbourhood. Large parking lot areas can have a wide impact.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Some weeks to 1 year => linked with the growth and coverage of plants
Life time	Grass block systems: depending on the used materials: app. 20-30 years Gravel turf: app. 30 years
Sustainability and life cycle	For the construction medium interventions are needed to be removed afterwards. Moreover, the plants can be composted and substrate/drainage recycled in most of the cases.
Management aspects (kind of interventions + intensity)	- No or limited irrigation - Mowing - Nutrients - 1-x interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Municipality departments (green space, roads, ...)
Technical stakeholders & networks	- Landscape architects - Specialized green spaces management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	nA

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • acrid salts • challenges targeted - Adequate substrate/soil volume - water management - Set up the maintenance (mowing)
Materials involved	- plants: grasses and herbs - substrate - drainage layer - perhaps kind of net/block structure -

II.5 Legal aspects related
nA

II.6 Funding Economical aspects	
Range of cost	Investment: 18-xx€ / m² Maintenance: 1 €/ m² /a Cheap and efficient solution: compared to paving or asphalt, just the half of it has to be calculated.
Origin of the funds (public, private, public-private, other)	nA

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with structural soils

Green parking lots can be combined with structural soil for the drainage and substrate body to maximize water retention and thus storm water runoff.

- Combination with rain gardens

Actual trend is to use planted areas to reduce storm water runoff and improve rainwater management by maximum retention of water and thus gain a load relief for sewerage. Specific substrates are improving the infiltration properties of tree pits.

Draingarden © Zenebio

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Substrate mixture and construction - Substrate/Soil quality and volume - The right plant choice
Limiting factors	- Difficulties of management - Soil contamination - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Sealed parking lot Cannot keep pace with greened version, but depending on load requirements.
Close NBS	• Unsealed parking lot • Green tram tracks The green parking lot address a wider diversity of impacts, by same time have limited restrictions regarding weight and use for transportation purpose.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

EPA (2008): Green Parking Lot Resource Guide. Environmental Protection Agency United States. Online: https://s3.amazonaws.com/nyclimatescience.org/Green%20Parking%20Lot%20Resource%20Guide.pdf

FLL (2007): Richtlinie für die Planung, Ausführung und Unterhaltung von Begrünbaren Flächenbefestigungen.

MCPC (2015): Sustainable Green parking lots Guidebook. Online: https://www.montcopa.org/DocumentCenter/View/9735

MCPC (nA): Green parking lots. Online: https://www.montcopa.org/DocumentCenter/View/3017

NRCSolutions (2017): Solution: Green parking lots. Online: http://nrcsolutions.org/wp-content/uploads/2017/03/NRC_Solutions_Parking_Lots.pdf

EU Green Concrete (nA): Schotterrasen – Parken im Grünen. Online: http://www.schotterrasen.at/service/informationsmaterial/GREEN%20CONCRETE%20Broschuere.pdf

EU Green Concrete (nA): What is gravel turf? Online: http://www.schotterrasen.at/e_schotterrasen/was_ist/inhalt.htm

IV.2 Sources used in this factsheet

www.green4cities.com

www.schotterrasen.at

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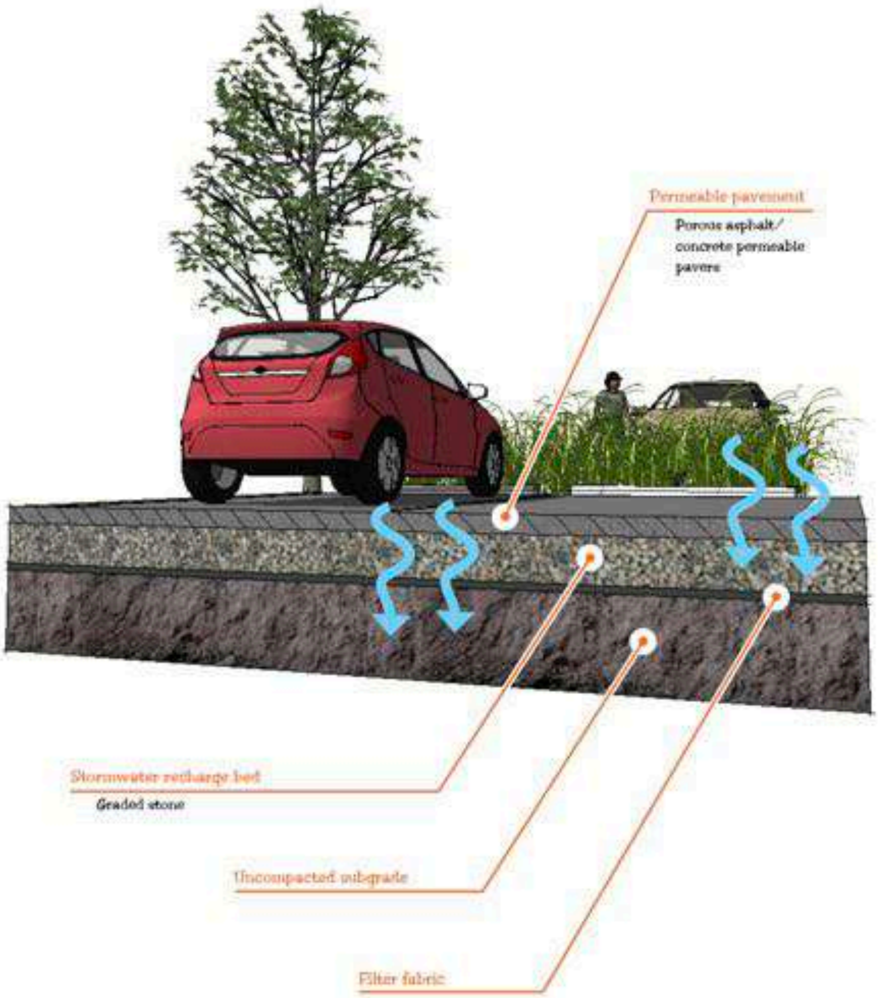
> UNSEALED PARKING LOT

I/ General description and characterization of the NBS types

I.1 Definition and different variants existing	
Definition	Unsealed parking lots are characterized by permeable surfaces for stormwater management. They can be used for low-traffic roads, parking lots, driveways or walkways.  Fig. Unsealed parking lot (MCPC, 2015)

Different variants existing

Two kinds can be distinguished, depending on the construction form respectively surface material:

=> Porous Asphalt & Concrete

It is an open-pored pavement mix which allows to let water pass through.

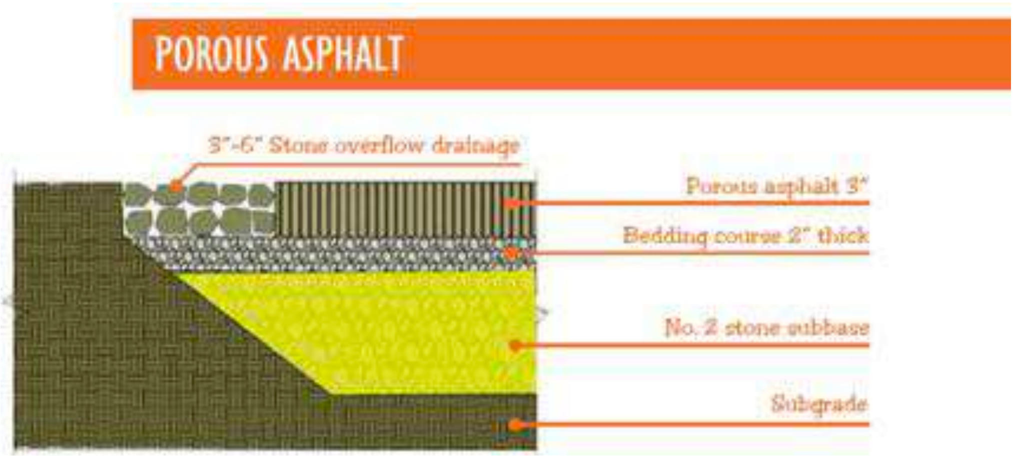


Fig. Porous Asphalt © MCPC 2015

=> Permeable interlocking pavement systems

This Type is characterized by permeability through little gaps between the concrete pavers, where water is able to run into the drainage storage bed.

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality 02-1 Urban water management and quality 02-2 Flood management	- Reduction of runoff water volumes. - Increasing water infiltration. - Minimizing floods effects. - Increasing flood protection.
Co-benefits and challenges foreseen	01| Climate issues 01-2 Climate adaptation	- Temperature reduction, increasing of evapotranspiration volume, mitigation of thermal, hot spots
Possible negative effects		

II/ More detailed information on the NBS types

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Object/Neighbourhood: Beside streets and sometimes on large areas.
Impacted scales	Depending on the size, but in most case the impact is limited to the building plot or the close neighbourhood. Large parking lot areas can have a wide impact.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Immediately
Life time	Depending on used materials, app. 15-60 years.
Sustainability and life cycle	For the construction medium interventions are needed to be removed afterwards. Moreover, substrate/drainage can be recycled in most of the cases.
Management aspects (kind of interventions + intensity)	Cleaning Preventing clogging - 3-x interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - municipality departments (roads, water ...)
Technical stakeholders & networks	- Landscape architects - Specialized construction companies. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	nA

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Adequate drainage layer - Water management - Set up the maintenance (surface cleaning)
Materials involved	- Paves or other permeable surfaces (porous asphalt or concrete) - Substrate - Drainage layer
II.5 Legal aspects related	
nA	
II.6 Funding Economical aspects	
Range of cost	Investment: 55-120€ / m² Maintenance: 1 €/ m² /a Compared to Greened parking lots higher investment is required by same maintenance costs but much less diversity of impacts.
Origin of the funds (public, private, public-private, other)	nA

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- Combination with structural soils Green parking lots can be combined with structural soil for the drainage and substrate body to maximize water retention and thus storm water runoff. **- Combination with rain gardens** Actual trend is to use planted areas to reduce storm water runoff and improve rainwater management by maximum retention of water and thus gain a load relief for sewerage. Specific substrates are improving the infiltration properties of tree pits.

Draingarden © Zenebio

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- choose correct pavement - adequate sub-construction
Limiting factors	- maintenance in winter (winter plowing, ...)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Sealed parking lot Similar, but with the big difference of permeability of water.
Close NBS	• Green parking lot The unsealed parking lot address a less diversity of impacts compared to the green version.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

MCPC (2015): Sustainable Green parking lots Guidebook. Online: https://www.montcopa.org/DocumentCenter/View/9735

UMD (2016): Permeable Pavement Fact Sheet. University of Maryland. Online: https://extension.umd.edu/sites/extension.umd.edu/files/_docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11%20Final.pdf

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Barnabás Körmöndi	MUTK	Reviewer
Marjorie Musy	Cerema	Reviewer

➢ On the ground

➢ Structures characterized by food and resources production

> VEGETABLES GARDEN

> URBAN ORCHAD

> URBAN VINEYARD

> URBAN FARM

I.1 Definition and different variants existing

Definition	This NBS is an area of land dedicated to the cultivation of vegetables, fruits and flowers, for the purpose of food production. This kind of solutions takes place in public spaces, community gardens or private residential property. Unemployed, retired people, families with limited resource or people interested in it are usually in charge of exploiting them.

Different variants existing:

Two main kinds can be identified, according to the type of garden and the gardening practice:

=> Variation in vegetable gardens: five types:

- Traditional: the most common vegetables grown here and others less common like celery
- Staple: only tomato and pumpkin
- Salad and herb: culinary herbs and traditional salad ingredients
- Complex: the cultivation of all kind of vegetables takes place, including less common species grown here, like mizuna, miners lettuce. Complex gardens produce the greatest volume of vegetables among those listed herein.
- Tomato and parsley: this garden has the most popular vegetables, for instance tomato, lettuce, courgette

Complex garden
© CARTIF

Garden with only lettuces, cabbage and parsley type
© CARTIF

Garden with aromatic plants (salad and herb)
© CARTIF

=> Variation in gardening practice: five types:

- Integrated: avoidance of chemicals and GMOs
- Chemical: in these gardens the use of inorganic pesticides and herbicides is allowed
- Informed consumer: private gardens cultivated by people interested in producing their own vegetables
- Soil: its main aim is to improve the soil quality
- Economic: they are managed by garden practitioners that sell the vegetables that they produce. Most of them have greenhouses.

Integrated garden
© CARTIF

Integrated and soil garden
© CARTIF

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 06| Resource efficiency 06-1 Food, energy and water 07| Public health and well-being 07-1Quality of life 07-2 Health 08| Environmental justice and social cohesion 07-1 Environmental justice 07-2 Social cohesion 09| Urban planning and governance 09-1 Urban planning and form	- Increasing the area of vegetation - Improve the quality of the urban environment and of soil - Provide a sustainable system of food sources - Social, educational and recreational space - Aesthetic value - Health benefits due to vegetable eating - Facilitate social interaction and community attachment - Improve the connectivity among green areas
Co-benefits and challenges foreseen	01| Climate issues 01-2 Climate adaptation 02| Urban water management and quality 02-2 Flood management 04| Biodiversity and urban place 04-1 Biodiversity 09| Urban planning and governance 09-1 Governance in planning	- Reduce the urban heat island effect - Reduce water run-off - Biodiversity: pollinating insects and birds have a safe place to feed, rest and thrive - Need to be integrated in cities
Possible negative effects	02| Urban water management and quality 02-1 Urban water management and quality	Waste in: - non-responsible irrigation - non adequate irrigation system - water contamination

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	object, neighbourhood
Impacted scales	The impacted scales are limited in most cases. It concerns the district itself or the close neighbourhood. In some cases, it can influence social groups by awareness raising. The aesthetic of that kind of intervention can contribute to well-being, educational activities and recreational activities.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1 year
Life time	Most edible plants have a vegetative cycle shorter than one year and these plants should be renovated every season. However, others like aromatic plants are pluriannual. The life time depends on the motivation of the people or city council involved in its management and maintenance, if the vegetable garden is public or not, etc.
Sustainability and life cycle	There are different kinds of plants for each season; this implies that vegetable gardens bring intensive cultivation activities. The most important activity starts in spring and continues until the end of summer, but several crops are cultivated in winter. On the other hand, they provide a sustainable way of food production for the whole year.
Management aspects (kind of interventions + intensity)	- Companion plants / Pest management - Regular irrigation according to the plants' needs - Pruning - Regular interventions - Weed control - Seedbed - Planting crops
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Agricultural engineer - Specialized green spaces management - Municipality - Owners
Technical stakeholders & networks	- Owners, co-owners (in case of a joint ownership property) or tenants - Gardeners
Social aspects	- The collective work that this NBS can result strengthens - Green solutions provide more motivation for participative and community activities

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of the companion plants: companion planting in gardening and agriculture is the planting of different crops in proximity for pest control, pollination, providing a habitat for beneficial creatures, and maximizing the use of space. All of these applications are focused on increasing the crop productivity and, consequently, this task is very important in order to improve ecosystem services from pollinators and reduce pesticide spraying.  *Tanacetum vulgare* L.: insecticide plant © CARTIF - Selection of plants depending on: • climate • soil • user preferences • containers / surface • irrigation system - Choose the support system taking into account the local climate (irrigation system) - Design the maintenance services in such a way that plants are well preserved throughout the whole process
Materials involved	- various plant types (vegetables, flowers, herbs) - containers - hand tools - irrigations system - other garden tools - nets against birds and box - water tank for rain water - seedbed - staking - shade netting  Staking and shade netting © CARTIF  Seedbed © CARTIF

II.5 Legal aspects related

- Permission for garden exploitation
- Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides
- Specific rules

II.6 Funding Economical aspects

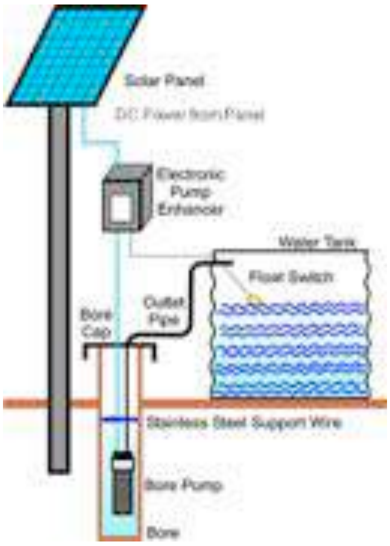
Range of cost	Depends on the size and owner: municipalities have gardening services which could achieve big amounts of low-cost and high quality materials, like compost or fertile land. At a Spanish conventional store: - fertile land: 0.15 €/l - tools: €50-150 (for 1-3 people) - drip irrigation system: €50-100/25m^2 - plants - containers - others: wooden stake, etc.
Origin of the funds (public, private, public-private, other)	Depending on the owner or community: - In private gardens, depending on the owner - In public gardens, the origin of the funds, usually, are from municipalities, since they are in charge of the administration and management of places where it could be installed. Nevertheless, occasionally the management is carried out by other kinds of entities (NGOs) which have different funding ways

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Community composting
© CARTIF

Birds feed
© CARTIF

Insect hotel
© CARTIF

 Vegetable garden watering with a fish tank Photo: FAO	- Combination with solar panels to the pump or other electrical utilities. (photo: http://www.solar-for-energy.com/solar-powered-water-pump.html) 

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Self-sufficiency and economical profit - Awareness raising (social relationships, educational)
Limiting factors	- Optimal conditions: e.g. solar exposition, soil quality
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	no
Close NBS	Urban farm Urban orchards Urban vineyard Insect hotels Beehives Composting Intensive green roofs

IV/ References

Nota:.IV.1 Scientific and more operational references (presented jointly)

Jamie B. Kirkpatrick, Aidan Davison, *Home-grown: Gardens, practices and motivations in urban domestic vegetable production.* Landscape and Urban Planning, Volume 170, 2018, Pages 24-33, ISSN 0169-2046

Bueno Mariano, *Manual práctico del huerto ecológico*. La fertilidad de la tierra, 2010. Navarra, Spain

Report of the conference committee for the follow-up to the independent external evaluation of FAO (CoC-IEE) Immediate plan of action. November 2008. Rome, Italy

IV.2 Sources used in this factsheet

Jamie B. Kirkpatrick, Aidan Davison, *Home-grown: Gardens, practices and motivations in urban domestic vegetable production.* Landscape and Urban Planning, Volume 170, 2018, Pages 24-33, ISSN 0169-2046

Bueno Mariano, *Manual práctico del huerto ecológico*. La fertilidad de la tierra, 2010. Navarra, Spain

Small-scale aquaponics food production. Integrated fish and plant farming. FAO, 2014. Rome, Italy

V/ Author(s)

Name	Institution / company	Writer/ reviewer
María González Ortega	CARTIF	Writer
Attila Kovács	SZTE	Reviewer
Marjorie Musy	CEREMA	Reviewer

Definition	It is an area of land devoted to cultivation, preferable in an organic way, of vegetables or fruits and flowers. These organic surfaces are located in the urban area. In general, non-profit associations, neighbourhood associations or the city council usually manage them. Unemployed, retired people, families with limited resources or people interested in it usually may exploit them. It is a social space where people and families profit of nature and healthy vegetables from orchards.

Different variants existing:

Different farming systems:

=> Furrow / in a row

The plants or seed are placed directly on the flat ground or on the top of the furrows.

Orchard in regular furrows © CARTIF

Orchard in regular furrows
© CARTIF

Orchard in regular furrows with drip irrigation
© CARTIF

=> Terrace:

Method of growing crops on sides of hills or mountains by planting on horizontal terraces that have been dug out into the slope. Though labour-intensive, the method has been effectively employed to maximize arable land areas in different kinds of terrains and to reduce soil erosion and water losses.

Orchard in terrace
© CARTIF

 Orchard in terrace © CARTIF	

=> Growing tables: the cultivation is on tables

Photo: www.gardeners.com

=> Keyhole or African orchard: it is a growing table with a composting basket in the centre

Key hole at the Agricultural university INEA in Valladolid
© CARTIF

=> Parades en crestall:
Divided cultivation; it must consist of at least 2 rectangles of land 1.5 m wide and 3 to 6 m long. These rectangles, called parades, are alternatively separated by two kinds of paths: straw and bricks paths, and only-straw paths. You can only walk along the straw paths, thus facilitating teaching especially to the little ones. At each parade a high density family of plants is cultivated to compete with the weeds. In addition, it is necessary to build as many parades as the number of rotations of cultivation that we want to make. Each parade has drip irrigation.

Parades crestall
© CARTIF

Parades crestall scheme
© CARTIF

=> Gardens on balcony and terrace: the cultivation of the vegetables is done in pots in private balconies and terraces

Balcony orchard
Photo: https://www.rojomenta.com/blog/consejos-huerta-urbana-balcones-terrazas/

Urban orchards in a terrace
© CARTIF

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 06| Resource efficiency 06-1 Food, energy and water 07| Public health and well-being 07-1Quality of life 07-2 Health 08| Environmental justice and social cohesion 07-1 Environmental justice 07-2 Social cohesion 09| Urban planning and governance 09-1 Urban planning and form	- Increasing the area of vegetation - Improve the quality of the urban environment and of soil - Provide a sustainable system of food sources - Social, educational and recreational space - Aesthetic value - Health benefits due to vegetable eating - Facilitate social interaction and community attachment - Improve the connectivity among green areas
Co-benefits and challenges foreseen	01| Climate issues 01-2 Climate adaptation 02| Urban water management and quality 02-2 Flood management 04| Biodiversity and urban place 04-1 Biodiversity 09| Urban planning and governance 09-1 Governance in planning	- Reduce the urban heat island effect - Reduce water run-off - Biodiversity: pollinating insects and birds have a safe place to feed, rest and thrive - Need to be integrated in cities
Possible negative effects	02| Urban water management and quality 02-1 Urban water management and quality	Waste in: - non-responsible irrigation - non adequate irrigation system - water contamination

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	object, neighbourhood
Impacted scales	The impacted scales are limited in most cases. It concerns the district itself or the close neighbourhood. In some cases, it can influence social groups by awareness raising. The aesthetic of that kind of intervention can contribute to well-being, educational activities and recreational activities.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1 year
Life time	It depends on the soil and how you use it. An intensive cultivation reduces lifetime, being able to make it unproductive in 6 months. If a suitable soil management is carried out, with its corresponding amendments, the useful life of the soil is infinite. Most edible plants have a vegetative cycle shorter than one year and these plants should be renovated every season. However, others like aromatic plants are pluriannual. The lifetime depends on the motivation of the people or city council involved in its management and maintenance, if the orchad is public or not, etc.

Sustainability and life cycle	A soil amendment will be made before the start of each growing season. Companion plants for soil improvement are recommended. There are different kinds of plants for each season; this implies that urban orchads bring intensive cultivation activities. The most important activity starts in spring and continues until the end of summer, but several crops are cultivated in winter. On the other hand, they provide a sustainable way of food production for the whole year.
Management aspects (kind of interventions + intensity)	- Agricultural machinery: cultivator, etc. - Companion plants / Pest management - Regular irrigation according to the plants' needs - Pruning - Regular interventions - Weed control - Seedbed - Planting crops
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Agricultural engineer - Specialized green spaces management - Municipality - Owners
Technical stakeholders & networks	- Owners, co-owners (in case of a joint ownership property) or tenants - Gardeners
Social aspects	- The collective work that this NBS can result strengthens - Green solutions provide more motivation for participative and community activities
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of the companion plants: companion planting in gardening and agriculture is the planting of different crops in proximity for pest control, pollination, providing a habitat for beneficial creatures, and maximizing the use of space. All of these applications are focused on increasing the crop productivity and, consequently, this task is very important in order to improve ecosystem services from pollinators and reduce pesticide spraying  *Tanacetum vulgare* L.: insecticide plant © CARTIF

	- Selection of plants depending on: • climate • soil • user preferences • containers / surface • irrigation system - Choose the support system taking into account the local climate (irrigation system) - Design the maintenance services in such a way that plants are well preserved throughout the whole process
Materials involved	- various plant types (vegetables, flowers, herbs) - containers - hand tools - irrigations system - other garden tools - nets against birds and box - water tank for rain water - seedbed - staking - shade netting  Staking and shade netting © CARTIF  Hand tools © CARTIF

II.5 Legal aspects related

- Permission for garden exploitation
- Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides
- Specific rules

II.6 Funding Economical aspects

Range of cost	Depends on the size and owner: municipalities have gardening services which could achieve big amounts of low-cost and high quality materials, like compost or fertile land. At a Spanish conventional store: - fertile land: 0.15 €/l - tools: €50-150 (for 1-3 people) - cultivator: 80-400€ - drip irrigation system: €50-100/25m^2 - plants - containers - others: wooden stake, etc.

Origin of the funds (public, private, public-private, other)	Depending on the owner or community: -In private gardens, depending on the owner -In public gardens, the origin of the funds, usually, are from municipalities, since they are in charge of the administration and management of places where it could be installed. -Nevertheless, occasionally the management is carried out by other kinds of entities (NGOs) which have different funding ways

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

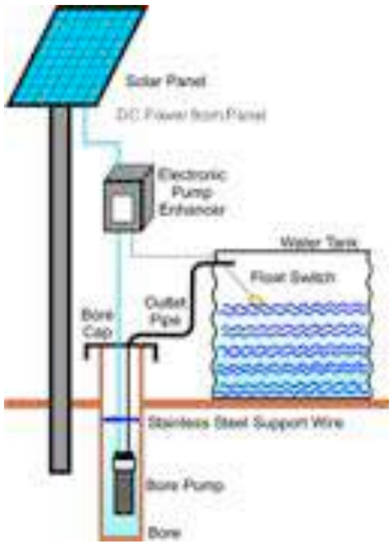
Community composting
© CARTIF

Birds feed
© CARTIF

Insect hotel
© CARTIF

Vegetable garden watering with a fish tank
Photo: FAO

- Combination with solar panels to the pump or other electrical utilities. (photo: http://www.solar-for-energy.com/solar-powered-water-pump.html)



III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Self-sufficiency and economical profit - Awareness raising (social relationships, educational)
Limiting factors	- Optimal conditions: e.g. solar exposition, soil quality - The type of soil is a conditioning factor because its quality and texture will depend on the choice of type and cultivation system, and overall in the lifetime, soil degradation is due to intensive cultivation. Soils in the urban gardens are often of very poor quality and with many construction waste, so large quantities of rubble should be removed and large amounts of fertile land added.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	no
Close NBS	Urban farm Vegetables garden Urban vineyard Insect hotels Beehives Composting Intensive green roofs

IV/ References

Nota:.IV.1 Scientific and more operational references (presented jointly)

Jamie B. Kirkpatrick, Aidan Davison, *Home-grown: Gardens, practices and motivations in urban domestic vegetable production.* Landscape and Urban Planning, Volume 170, 2018, Pages 24-33, ISSN 0169-2046

Bueno Mariano, *Manual práctico del huerto ecológico*. La fertilidad de la tierra, 2010. Navarra, Spain

IV.2 Sources used in this factsheet

http://www.gasparcaballerodesegovia.net/es/

Urban GreenUP project "New Methodology to Re-naturing Cities through Nature-Based Solutions (NBS)". This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730426.

https://www.britannica.com/topic/terrace-cultivation

EKLIPSE Project, Knowledge & Learning Mechanism in Biodiversity & Ecosystem Services. http://www.eklipse-mechanism.eu/

V/ Author(s)

Name	**Institution / company**	**Writer/ reviewer**
María González Ortega	CARTIF	Writer
Attila Kovács	SZTE	Reviewer
Marjorie Musy	CEREMA	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This is an urban area where grapes are grown for market sales and for wine making. First, it plays a metaphoric role in the urban green spaces – it brings back the historicity of the landscape, provides space for activity of people near the nature, thus this NBS entity has great social and mental relevance. The capacity of the vineyard in the carbon - sink should be mentioned too. The vineyards could represent a crucial cropping system able to provide pivotal ecological services such as carbon dioxide sequestration. Viticulture can also contribute to the preservation and regulation of natural resources, such as soil and agricultural landscapes.

Different variants existing

Two kinds can be identified, depending on the spatial location and the ownership

=> Spatial location

a. Urban vineyard in the historic city (this vineyard areas are made from the old time, in historic wine producing regions)

b. Urban vineyard in the modern city (this vineyards are made from the new time of the cities, first of all from practical and social reasons

a. Mazzorbo Island,Venice
https://vinepair.com/wine-blog/7urban-vineyards-hidden-worlds-great-cities//

b. Vienna, Austria
http://www.viennasights.at/vienna-for-foodies/

=> Ownership

a. Community ownership,
b. Private owner

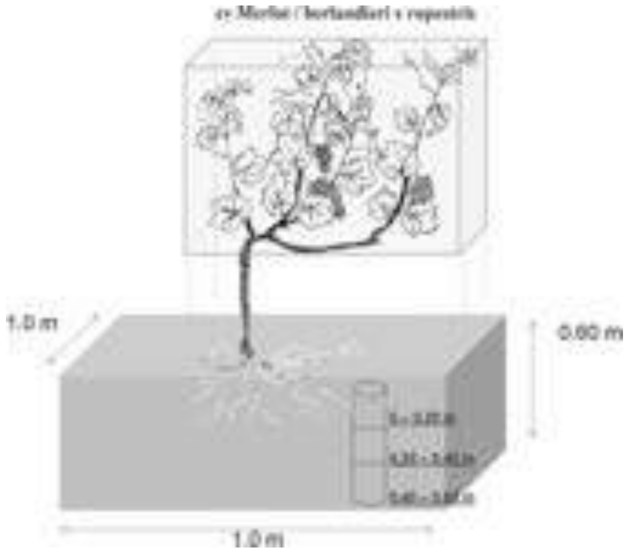
Thessaloniki, Greece
https://vinepair.com/wine-blog/7urban-vineyards-hidden-worlds-great-cities/

Brooklyn, New York
https://www.bkreader.com/2017/09/rooftop-reds-vineyard-made-brooklyn/

=> Cultivation way by quality or space for of the soil

a. Above ground - if the quality of the soil is adequate and the depth and quantity is enough

b. In container or raised bed – if it need the good soil, because the soil is contaminated or the farm is located on the roof



Carbon sink model for the above-and -below-ground biomass determination in grapevine.
(Brunori et al. 2016)

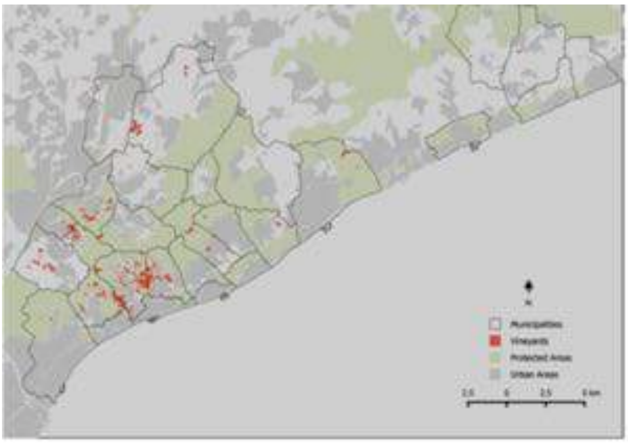
Cleveland Neighbourhood, 2015
https://popupcity.net/urban-vineyard-helps-revitalize-cleveland-neighborhood/

Brooklyn, New York
https://www.bkreader.com/2017/09/rooftop-reds-vineyard-made-brooklyn/

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and Urban space 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 06| Resource efficiency 06-1 Food, energy and water 07| Public Health and well-being 07-2 Quality of Life 11| Green Economy 11-3 Direct economic value of NBS	-Improve the quality of urban environment and soil -Active recreation and community spirit -The subsistence of district is improved - Aesthetic and patrimonial value, -The economic profits are equal to conventional agricultural profits
Co-benefits and challenges foreseen	01| Climate issues 01-1 Climate Mitigation 01-2 Climate adaptation 04| Biodiversity and Urban space >04-1 Biodiversity 08| Environmental justice and social cohesion 08-2 Social cohesion	-The capacity of the carbon sink (The root system's contribution to total C storage ranged from 9% to 26%. The highest level of soil organic C was found in the organic vineyard. Total C storage in the vineyard ranged from 5,7 to 7,2tC ha-1 year -1. - Contribute to mitigate urban heat island effect - Provide an habitat for birds and insects - In the case of community vineyard, create social cohesion
Possible negative effects	02| Water management 02-1 Urban water management and quality 07| Public Health and well-being	- The increased utilization of water in summer period - Presence of undesired insects and pests

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales	
Scale at which the NBS is implemented	District, neighbourhood   *(photo: Jókai Garden in Budapest, by Szalay3 and Barnabas Kormondi)*

Impacted scales	The impacted scales are in most of case limited. It concerns to the district itself or the close neighbourhood. But in many cases, the impacted scale is much larger. It can influences several social groups by awareness raising.  Fig. 2. Vineyards of the PDO Alella. The Alella wine region within the Barcelona Metropolitan Region. (The adaptation of urban farms to cities: The case of the Alella wine region within the Barcelona Metropolitan Region by Xavier Recasens, Oscar Alfranca, Luis Maldonado – Land Use Policy, 2016)
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	2 to 4 years => It depends on the types of vineyards grown.
Life time	It depends on motivation of the citizens, vine diseases and vineyard productivity throughout its life. With the correct maintenance, their average life could be 50 years old
Sustainability and Life Cycle	As organic material most of the produced waste can be treated at the urban waste collection circuit.
Management aspects (kind of interventions + intensity)	- No or limited irrigation. - Pruning - Interventions are often needed as control of diseases or pests
II.3 Stakeholders involved	
Technical stakeholders	- Wine growers monitors - Specialized green spaces management firms. - Landscape architects
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Neighbourhood organizations eventually municipality provides land plots for vineyards
Social aspect	The formation of a community can be emerged, or it can be strengthen due to the collective work; - Green solutions are popular in the participative processes

II.4 Design / techniques/ strategy

Knowledge and how-know involved **Or key points for success**	- Grape varieties selection adapted to: • the local climate, • the soil properties - Chose the support system materials well adapted to the local climate - Pruning kills for plants such as grapevine - Set up the maintenance needs in the right frame directly linked with the grape varieties
Materials involved	- grape plants - poles and wire - containers - hand tools - other garden tools - nets against birds and box - fertilizers - pesticides

II.5 Legal aspects related

- Permission for creating community urban vineyards is given by the municipality, or in case of a private property, they don't need any permission.
- Local watering regulations
- Local pesticides regulations

II.6 Funding Economical aspects

Range of cost	Investment: 50-100 € / m² (plants, tools, poles and wires, soil preparation, etc.) Running cost: to 30-120€ / m² - substitutions of poles and wires, - hands tools - fertilizers - pesticides
Origin of the funds (public, private, public-private, other)	Depending of the owner or community. - Private owner, private funds - Community funds - Public property , investment cost supported by the municipality

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

=> Combine with a green roof

Source: Brooklyn, New York (https://gardencollage.com/nourish/farm-to-table/growing-grapes-brooklyn-rooftop-reds-shaping-future-urban-winemaking/)

=> Vegetation engineering systems for slope erosion control

Source: Montmarte, Paris, *By MonsieurRoi [CC-BY-SA-3.0], via Wikimedia Commons*
https://vinepair.com/wine-blog/7urban-vineyards-hidden-worlds-great-cities/

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Appropirate climate and solar access - Appropriate soil quality - Awareness raising (social relationships, education)
Limiting factors	- The community motivation decreasing. - Difficulties for the correct management
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	n/
Close NBS	Vegetable garden Urban orchard Insect hotels Beehives Mulching

IV/ References

Note: references presented below are often common with the whole category …

IV.1 Scientific and more operational references (presented jointly)

- Brunori, Elena & Farina, Roberta & Biasi, Rita. (2016). Sustainable viticulture: The carbon-sink function of the vineyard agro-ecosystem. Agriculture, Ecosystems & Environment. 223. 10-21. 10.1016/j.agee.2016.02.012.
- Chiara Camaioni, Rosalba D'Onofrio, Ilenia Pierantoni & Massimo Sargolini (2016) Vineyard landscapes in Italy: cases of territorial requalification and governance strategies, Landscape Research, 41:7, 714-729, DOI: 10.1080/01426397.2016.1212323
- Xavier Recasens, Oscar Alfranca, Luis Maldonado (2016) The adaptation of urban farms to cities: The case of Alella wine region within the Barcelona metropolitan region, Land Use Policy, 56, 158-168, doi.org/10.1016/j.landusepol.2016.04.023.
- Jennifer Cockrall-King, Food and the City: Urban Agriculture and the New Food Revolution by, Prometheus Books, 2012.
- Antonio Tomao, Valerio Quatrini, Piermaria Corona, Agostino Ferrara, Raffaele Lafortezza, Luca Salvati (2017) Resilient landscapes in Mediterranean urban areas: Understanding factors influencing forest trends, Environmental Research, 156, 1-9. doi.org/10.1016/j.envres.2017.03.006.

IV.2 Sources used in this factsheet

- Wilson Helman: By Growing Their Grapes in Brooklyn, Rooftop Reds Is Shaping The Future of Urban Winemakin, gardencollage.com, 2016
- Joshua Malin, 7 Urban Vineyards hidden in the world's great cities, Vinepair
- http://popupcity.net/urban-vineyard-helps-revitalize-cleveland-neighborhood/
- https://urbanwinegrower.wordpress.com

V/ Authors

Name	Institution / company	Writer/ reviewer
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Marta de Regoyos	ACC2	Reviewer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	The **Urban Farm** is an intentional effort by an individual or a community to grow its capacity for self-sufficiency and well-being through the cultivation of plants and/or animals (mainly poltries, connect to garden, secondary activity, not separated animal farm). For-profit or non-profit organizations that are growing produce flowers, herbs and/or animals within a city. These for-profit organizations have a paid staff that grows products for sale for a local market only.

Different variants existing

Three kinds can be identified, depending of the spatial location, the ownership and the cultivation way by quality of the soil:

=> Spatial location

a. Urban farm on the ground: if the territory is available in city, between the living area

b. Urban farm on the roof: this form is usually takes place near to the city center with big density, where the built-in ratio is high, as well the property prices, but the human and social requirements exist.

Seattle Urban Farm
http://latimesblogs.latimes.com/home_blog/2012/03/breaking-through-concrete.html

Massachusetts Rooftop Urban Farm
https://foodtank.com/news/2015/11/urban-farming-hits-the-big-leagues/

=> ownership

a. Private owner

b. Community ownership

=> cultivation way by quality of the soil

a. Above ground: if the quality of the soil is adequate and the depth and quantity is enough

b. In container or raised bed: in the case of contaminated or bad quality soil or for the farms located on roofs

Detroit Urban Farm
http://www.miufi.org/projects

Mountain view Cohousing, Canada
https://sagecohousinginternational.org/

Hong Kong Rooftop Urban Farm
https://gogreenhongkong.com/2014/08/30/rooftop-farming-in-hong-kong/

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and Urban Place 04-2 Urban space development and regeneration 07| Public Health and well-being 07-2 Quality of Life 09| Urban planning and governance 09-1 Urban planning and form 11| Green Economy 11-3 Direct economic value of NBS	-Improve the quality of the urban environment and of soil -Active recreation and community spirit - Limit urban sprawl -The subsistence of district is improving -The economic benefits are equal with the conventional agricultural benefit
Co-benefits and challenges foreseen	01| Climate issues 01-2 Climate Mitigation 01-2 Climate Adaptation 04| Biodiversity and Urban Place 04-1 Biodiversity 06| Resource efficiency 06-1 Food, energy and water	- Proximity food: reduce greenhouse gas emissions for transportation - Contribute to Reduce the urban heat island effect - Provide an habitat for birds and insects -According to food supply chain is requires less transport and logistic system
Possible negative effects	02| Water management 02-1 Urban water management and quality	- the increased utilization of water in summer period

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales	
Scale at which the NBS is implemented	District, neighbourhood Private plots or families
Impacted scales	The scales impacted are in most of case limited. It concerns the district itself or the close neighbourhood. But in many cases, the impacted scale is much larger. It can influence several social groups by awareness raising. The most important role of the Urban Farm is perhaps in the physical manifestation of the vision for a truly sustainable food system, and in the bringing together of the people who can make that happens. The Urban Farm is an ideal platform for generating dialogue among various parts of a community.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1 season to 1 or -2 years: it depends on the types of the grown vegetables or plants but most vegetables are seasonal.
Life time	It depends on motivation of the involved people
Sustainability and life cycle	The cultivation of an urban farm is supposed to be intensive, thus its sustainability highly depends on its location, climatic aspects and the chosen plants. In most cases it replaced annually, its lifecycle expanded only to the vegetation period of a certain year. Most of waste produced in it is organic waste. There are other types of waste materials as plastics or paper that can be treated at the urban waste collection circuit The future: Visionary Home Farm combine retirement homes and vertical urban farms (Inhabitat)

	 Homefarm by SPARK https://www.dezeen.com/2015/11/17/home-farm-spark-model-asian-retirement-housing-communities-city-farms/
Management aspects (kind of interventions + intensity)	- Need regular irrigation - Daily intervention or weekly care
II.3 Stakeholders involved/ social aspects	
Technical stakeholders and network	- Gardeners and farmers - Monitors specialized in green spaces management, horticulturists - Landscape architects
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Community ownership, eventually neighbour or municipality
Social aspects	- The formation of community can be emerged, or it can be strengthen due to the collective work; - Green solutions are popular in the participative processes
II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	- The selection of plants and animals must be adapted to: • the local climate • plot space • water availability • soil and air quality • animal farms regulations • kind of material needed for cultivation and harvesting - Chose the support system well adapted to the local climate (irrigation system) - Set up the maintenance keeping plants in the right frame

Materials involved	- various plant types (vegetables, flowers, herbs) - containers - hand tools - irrigations system - other garden tools - nets against birds and box - water tank for rain water

II.5 Legal aspects related

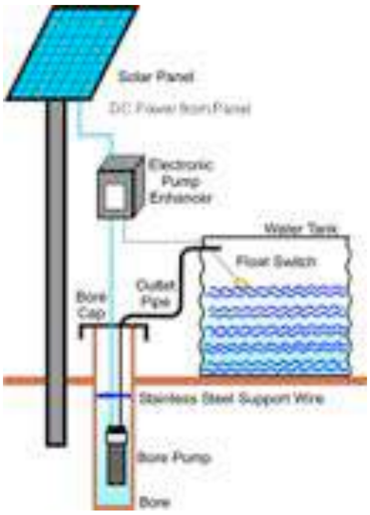
Permission for creating community urban farm is given by the municipality, or in the case of private property the owner gives the authority.
Local farms regulations
Local watering regulations
Local pesticides regulations

II.6 Funding Economical aspects

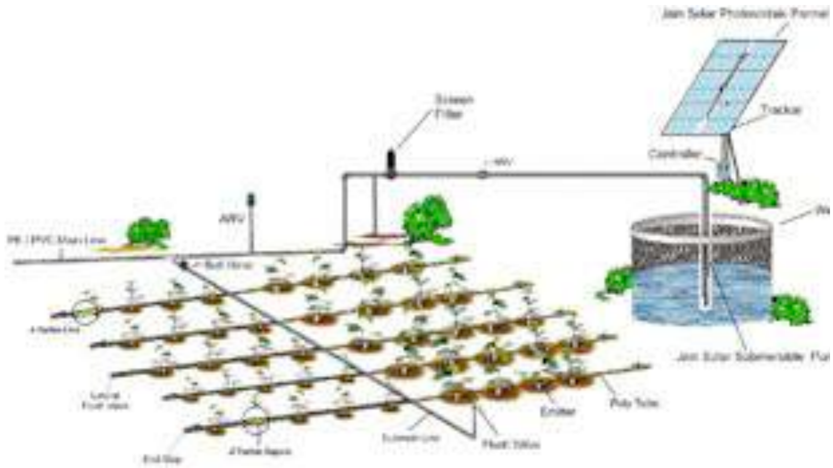
Range of cost	Investment: 10-60€ / m² It is depended the quality of the soil in a great measure. Maintenance only the watering fee, other maintenance is overhead.
Origin of the funds (public, private, public-private, other)	- Depending on the urban farm ownership. Normally in case of municipality ownership, the city hall provide the main cost of infrastructure and then the community of farmers bring their own tools and materials

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with solar panels to the pump or other electrical utilities.



Solar water pump (photo: http://www.solar-for-energy.com/solar-powered-water-pump.html)



Effective irrigation system, combination with solar panels to the pump or other electrical utilities, (photo: http://www.renewableenergyfocus.com/view/44586/solar-powered-irrigation-a-solution-to-water-management-in-agriculture/)

- Combination with composting the organic residues	 Compost (photo by Handyman)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Self-sufficiency and economical profit - Awareness raising (social relationships, education)
Limiting factors	- Finding plots with adequate factors for the cultivation or the production (the factors are: soil quality, low atmospheric pollution, solar light access, accessibility); - Maintenance of community motivation; - Needs of management.

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	No
Close NBS	Vegetable garden Urban orchard Urban vineyard Insect hotels Beehives Mulching Composting Intensive green roofs

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- Nathan McClintock; Why farm the city? Theorizing urban agriculture through a lens of metabolic rift, *Cambridge Journal of Regions, Economy and Society*, Volume 3, Issue 2, 1 July 2010, Pages 191–207, https://doi.org/10.1093/cjres/rsq005
- H. De Zeeuw, R. Van Veenhuisen, M. Dubbeling. The role of urban agriculture in building resilient cities in developing countries. *The Journal of Agricultural Science, 149*(S1), 153-163, 2011. doi:10.1017/S0021859610001279

Specht, K., Siebert, R., Hartmann, I. et a l. Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings, Agric Hum Values (2014) 31: 33. https://doi.org/10.1007/s10460-013-9448-4

IV.2 Sources used in this factsheet

- David Hanson and Edwin Marty: Breaking Through Concrete – Building and Urban Farm Revival, University of California Press, Berkeley, Los Angeles, London – 2012, e-book
- T. Angott, Urban agriculture: long -term startegy or impossibble dream? Public Health, 04/2015

-www.paintedsunsetfarm.com
- www.seedstock.com

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➢ On the ground

➢ Ecological restoration

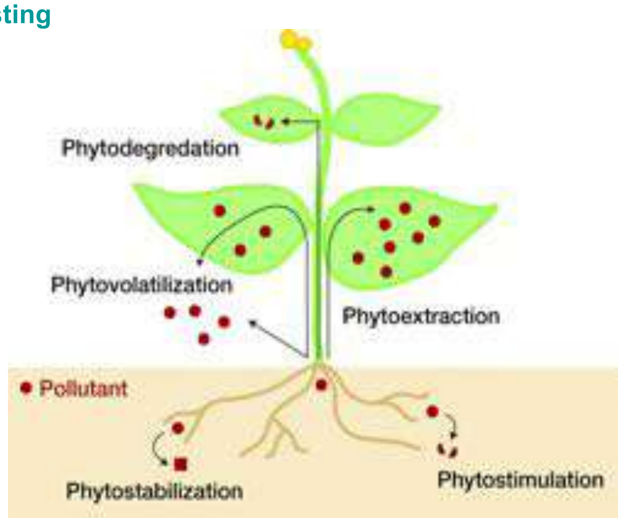
> MANAGEMENT of POLLUTED AREAS by PLANTS (PHYTOREMEDIATION)

> MANAGEMENT of POLLUTED AREAS by PLANTS (PHYTOREMEDIATION)

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	T his NBS is based on the use of plants and trees and their interactions with microorganisms for the treatment of polluted soils. The concept is very broad and therefore covers a range of relatively different technologies. We should talk about phytoremediations.

Different variants existing



Mode of action of plants on soil pollutants (*Pilon-Smits, 2005)*

Phytoremediation brings together four different modes of action:

=>Phytostabilisation

The surface is protected against degradation phenomena, which limits the transport of particles charged with pollutants by water and wind. When you implant a plant cover, it stabilizes the soil.

=>Phytoextraction

This is the principle of the vacuum cleaner. The plant takes pollutants by its roots. They are transferred to the aerial parts where they are sequestered.

=>Phytodegradation

This process results primarily from the stimulation of biological activity, which can contribute to the degradation of organic pollutants as the result of plant enzymes, with the production of carbon dioxide, but also of intermediate products. With the help of rhizospheric microorganisms to transform organic pollutants, it is called rhizoremediation.

=>Phytostimulation/ rhizodegradation

This is a stimulation of the biodegradation activity of organic contaminants in the roots (rhizosphere)

=>Phytovolatilization

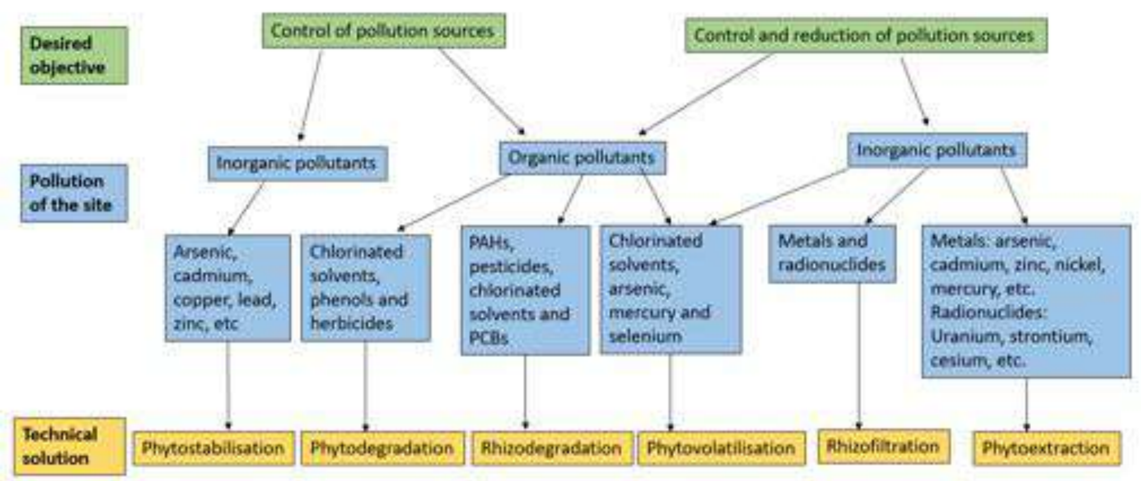
This process is an extension of phytoextraction, since the plant is capable of volatilizing pollutants. Plants can also transform trace elements that then take on volatile chemical forms.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	05| Soil management >05-1 Soil management and quality	- Rehabilitation of polluted sites - Can restore or manage soil fertility (Alori, 2012)
Co-benefits and challenges foreseen	02| Water management and quality > 02-1 Urban water management 04| Biodiversity and urban space >04-1 Biodiversity >04-2 Urban space development and regeneration 06| Resource efficiency >06-2 Raw materials 07| Public health and well-being >07-3 Health 11| Green economy >11-3 Direct economy value of NBS	- Phytopurification - Provide a habitat for living beings - Extraction of valuable metals (phytomining) - A successful phytoextraction reduces the total or bioavailable concentrations in urban soil below the threshold at which they are recognized to present a risk to human health, groundwater, or other receptors (Dickinson et al., 2009)"
Possible negative effects	07| Public health and well-being >07-3 Health 11| Green economy >11-1 Circular economy	- Presence of undesired insects - Recovery of contaminated residues (ashes)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	In the cities, in a garden on an individual scale as along streets, roads…
Impacted scales	The scales impacted are in most of case limited It concerns the area to be cleaned up or the close neighbourhood.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Long treatment time: on average 5 to 10 years. The main factor determining the duration of phytoextraction is the mass of PTEs (Potentially Toxic Elements) removed by the crop per unit of time (years) compared to the mass of PTE in the soil.
Life time	The time of the depollution. For example, Dushenkov, D. (2003) founded that for Phytovolatilization has been successful in tritium (3H), a radioactive isotope of hydrogen, it is decayed to stable helium with a half-life of about 12 years. However, it is possible to keep the plants or trees on the site cleared for the entire life of them.

Sustainability and life cycle	Phytodegradation, phytoextraction and phytostimulation are solutions on long term, because they allow then a re-use of depolluted soil. Regarding phytoextraction, it implies the exportation and the treatment of green debris (considered as wastes), to be a solution on long term. At the opposite phytostabilisation is temporary solution, it fixes the pollutants, but the area remains polluted.
Management aspects (kind of interventions + intensity)	Little or no maintenance of plants, bur fertilisation is necessary in certain cases.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	The public, the owner of the site, non-governmental organizations, the owners of neighbouring sites
Technical stakeholders & networks	Companies or associations specialized in depollution
Social aspects	Requires a lot of time
II.4 Design/techniques/strategy	
Knowledge and how-know involved	- Identify the appropriate phytotechnology according to the type of contamination (cf. diagram) - Select the appropriate plants or trees to the type of contamination and the local climate (almost all contaminants can be treated with varying efficiency) - Can be used alone or in combination with other decontamination techniques (e.g., bioremediation) - Generally used on large sites (plants or trees need space for growth) - Contaminant concentration assessed from low to medium- Better that the contamination is shallow (<5m)



Flow diagram to identify appropriate phytotechnology by type of contamination (Bert, 2013)

Materials involved	No specific material is required

II.5 Legal aspects related

- Lack of specific regulations for polluted soils
- To install plants or trees on a polluted site, you should have the agreement of the owner of the site.

II.6 Funding Economical aspects

Range of cost	- Low cost of decontamination (up to 10 times lower than conventional techniques) - Ex for a lead contaminated site: - Conventional in situ decontamination techniques: estimated cost between 15 and 50 €/t (venting), 40 and 120 €/t (oxidation or reduction), 15 and 50 €/t (bioventing) - Phytoremediation technique: estimated cost between 2 and 40 €/m^2 (i.e. 3.5 and 70€/m^2)
Origin of the funds (public, private, public-private, other)	- Depending of the owner of the polluted site - Public structures (to be consulted for each country) are involved in the financing of the depollution activities - Territories invested in reconversion of polluted site (municipalities, regions…) - European fund (e.g. the ERDF 2014-2020 program finances projects involving soil remediation)

II.7 Possible combinations with other kinds of solutions

- Possibility of combining different soil remediation techniques to increase the performance and reduce the number of treatments:
- Interaction bioaugmentation / phytoremediation
- Interaction phytoextraction / energy recovery of biomass (soil remediation and use of biomass to produce energy, biocatalysers)
- Multiprocessing phytoremediation system

- Double benefits:
- Phytoremediation / agromine: Soil remediation, biomass production and metal extraction (metals contained in plants are separated and purified to produce high value added salts)

The blue sap of Pycnandra acuminata (accumulation of nickel by this tree species)
(photo: Antony van der Ent)

III. Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Use the correct plant and the appropriate phytotechnology according to the type of contamination -The decontaminated area must not exceed more than 50 cm deep (except in case of decontamination by trees)
Limiting factors	-The treatment is impossible if the pollutants are distributed too heterogeneously -Treatment is not possible if pollutant concentrations are too high -Treatment times are important

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Traditional techniques: -Excavation is the technique of extracting soil from the soil before processing. - Containment (polluted soil) which consists of installing an underground bulkhead to prevent the migration of pollutants to the water table. - Washing (contaminated soils) stimulates the circulation of active agents added to the water in the soil, in order to release and entrain the organic products, which are then separated by decantation at ground level.
Close NBS	Constructed wetland for phytoremediation.

IV/ References

Alori, E., & Fawole, O. (2012) Phytoremediation of soils contaminated with aluminium and manganese by two arbuscular mycorrhizal fungi. Journal of Agricultural Science, 4(8), 246

Armando C., (2017), Soil Pollution : From Monitoring to Remediation, Academic press, 314pp

Bert, V. (2013). Les phytotechnologies appliquées aux sites et sols pollués (pp. 100-p). EDP Sciences. Paris.

Chevier E., (2013), La Phytoremédiation, une solution d'avenir pour le Québec, https://www.usherbrooke.ca/environnement/fileadmin/sites/environnement/documents/Essais_2013/Chevrier_E__2013-09-09_.pdf (website consulted the 24th january 2018)

Dickinson, N. M., Baker, A. J., Doronila, A., Laidlaw, S., & Reeves, R. D. (2009). Phytoremediation of inorganics: realism and synergies. International Journal of Phytoremediation, 11(2), 97-114

Dushenkov, D. (2003): Trends in phytoremediation of radionuclides. – Plant and Soil. 249; 167-175.).

United Nations Environment Program (UNPEP), 2002, Phytoremediation : An Environmentally sound technology for pollution prevention, control and remediation, http://www.unep.or.jp/ietc/Publications/Freshxater/FMS2/1.asp (website consulted the 25th january 2018)

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➢ On the ground

➢ Choice of plants

> USE OF PREEXISTING VEGETATION

> INTRODUCED PLANTS

> VEGETATION DIVERSIFICATION

> USE OF PRE-EXISTING VEGETATION

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

This NBS can preserve a part of pre-existing ecosystems and vegetation The use of pre-existing vegetation (remnant vegetation) provides elements to integrate vegetation present on the site prior to NBS design and implementation.
This approach has many advantages (Florgård, 2000):

- Vegetation in parks, etc. is already mature when the first occupants move in. This is a great advantage especially in areas with low growth potential.
- Preserved areas will differ from ‘traditional’ gardens and parks and be of interest to everyone, particularly as an exciting playground for children.
- Costs for construction and maintenance of green areas are minimized
- Essential habitats for plants and animals can be preserved.

Different variants of pre-existing vegetation

The preserved remnant vegetation can be natural or semi-natural which has been developed with little or non-human intervention over time. It may be related to agricultural, forestry or other uses.
It also comprises stable post-agricultural plant communities such as meadows and pastureland, or even pre-existing vegetation in urban areas.

Horticultural hedge
(Source: Titus Tscharntke, Pixnio)

Semi-natural hedge
(Source: Adeline Bulot)

Illustration of horticultural hedge v/s Semi-natural hedge

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Remnant hedges preserved in urban areas
(Source: H. Daniel)

Suburban areas with horticultural hegdes
(Source: Ramblersen, Wikimedia commons)

Illustration of suburban areas with planted horticultural hedges v/s trees or preserved semi-natural hedges in a landscape planning

Semi-natural space (ex: urban park)
(Source: Mbzt, Wikimedia commons)

Botanical garden
(Source: Creative commons)

Illustration of semi-natural space v/s botanical garden

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity 07| Public Health and well-being > 07-2 Quality of life	- Increase of biodiversity - Provide a habitat for birds and insects, and other animals - Aesthetic value - Contact with nature - Support for education
Co-benefits and challenges foreseen	01| Climate Issues > 01-1 Climate mitigation > 01-2 Climate adaptation 2| Water Management > 02-1 Urban water management 03| Air quality > 03-2 Air quality locally	- By already grown plant acts in favour of urban heat island reduction and helps filter air and water pollutants - Keeping vegetation is in favour of carbon sequestration
Possible negative effects	07| Public Health and well-being > 07-3 Health	- Presence of undesired insects - Presence of weeds - Allergies

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: a green space. The quarter: diversity of plants for example can be done at the quarter scale in order to diversify ecological habitats (forests, open herbaceous areas, …) The city: planning of green infrastructures
Impacted scales	The 3 scales impacted Regional scale is also impacted when ecological connectivity is ensured
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Immediately when the pre-existent vegetation is conserved.
Life time	It depends on several factors: - The protection measures implemented to preserve plants during the urban works. - For rural plants integrated in a city - Long term, it depends mainly on vegetation management
Sustainability and life cycle	This type of vegetation is often more resilient
Management aspects (kind of interventions + intensity)	This type of vegetation most often requires a continuation of previous management conditions, the most often of low intensity.
II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Users of public areas - Municipality
Technical stakeholder's networks	- Landscape architects - Landscape planners at the city scale - Specialized green spaces management firms, horticulturist and gardeners. - Naturalists' NGO - horticultural producers
Social aspects	Environmental education, Awareness campaign, training, participatory process, nature conservation
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • challenges targeted • the traffic intensity (the level of perturbation) - Vegetation management - Botanical skills - Landscape architecture and landscape planning skills
Materials involved	- Inventory of existing plants - Maps of ecological habitat

II.5 Legal aspects related
Invasive plants (List of plants established by IUCN, www.griis.org) Protected plants (The IUCN Red List of threatened species, www.iucnredlist.org), refer to national laws Laws and regulations in each country (for example: classification “Espaces Boisés Classés”, related to the protection of wooded areas in towns, defined by the urbanism code in France).

II.6 Funding Economical aspects	
Range of cost	Preserving existing vegetation is a way to reduce both design and management cost
Origin of the funds (public, private, public-private, other)	- Depending of the owner

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- Every NBS using vegetation

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Ecological and botanical knowledge and awareness of landscape architects and urban green spaces mangers (it is very variable following actors) - Cooperation been landscape architects with different sensibility: for example for designing the green skyline in NY, James Corner (Landscape architect and project manager leader) called in Piet Oudolf (a garden designer with deep knowledge in botany) for the planting design.
Limiting factors	- The availability and diversity of plants in horticultural trade (Bergues 2010) - The constrains of the urban ecosystem in dense city that limit the palette to fewer plants - Habits/ “traditions” in landscape architecture (for example: monospecific street tree)

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- See factsheets of the different NBS using vegetation Urban vegetation with poor diversity is more sensitive to pests and diseases. It implies more intensive management and often-chemical treatments.
Close NBS	- See factsheet “choice of plant –vegetation diversification” - See factsheet “choice of plant – introduced plants” - See factsheets of the different NBS using vegetation

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Florgard C. 2009. Preservation of original natural vegetation in urban areas : an overview. In Ecology of Cities and Towns : a Comparative approch, Ed M.J. McDonnell, A. Haas & J. Breuste, Cambridge University Press, pp 380-398

Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography, 21(5), 545-555.

List of plants established by IUCN, www.griis.org

The IUCN Red List of threatened species, www.iucnredlist.org

Trees in Hard Landscape – A guide for delivery. 2014. Trees and Design Action Group.

UFEI - SelecTree: A Tree Selection Guide: hppts://www.selectree.calpoly.edu

IV.2 Sources used in this factsheet

Florgård, Clas. « Long-term changes in indigenous vegetation preserved in urban areas ». Landscape and Urban Planning 52(2): 101 16

Bergues Martine, 1992, Arbres des pépinières, arbres des paysages : une étude de logiques professionnelles, SRETIE Ministère de l'Environnement / Ecole Nationale Supérieure d'horticulture / Ecole Nationale Supérieure du Paysage, Rapport final, 174 pages.

Bergues, Martine. 2010. "Fleurs jardinières et fleurs fleuristes." *Ethnologie française* 40 (4): 649–56. https://doi.org/10.3917/ethn.104.0649.

Hitchmough, James. 2011. "Exotic Plants and Plantings in the Sustainable, Designed Urban Landscape." *Landscape and Urban Planning at 100* 100 (4): 380–82. https://doi.org/10.1016/j.landurbplan.2011.02.017.

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Introduced plants are new plants that are voluntarily added and that can be solutions in themselves to identified environmental challenges The choice of introduced plants could be considered as a detail of several NBS using vegetation. It is true that it is a part of many other NBS, but actually it also can be considered as a NBS in itself. It is especially important for biodiversity purposes, ecological processes and for the quality of urban green spaces practises.

Different categories to classify introduced plants:
This selection of introduced plants refers to several categories of plants that are in relation to environmental, ecological and aesthetics purposes.

a. Biogeographical origin of plant species or plant populations

- *Indigenous species / exotic species*

Indigenous species (or native species) are species naturally present in the considered biogeographical area. They are opposed to exotic species, which grow outside of their biogeographical origin, due to voluntary or involuntary human introduction.
Both types of plants can be offered by horticulturists. For indigenous plants, local transplants can also sometimes be undertaken (seed or vegetative parts, cutting of plants, especially for woody plants). In this case, it is necessary to respect local law that preserve natural areas.

- *Indigenous species of local origin (plant population)*

Another approach can still be added for the choice of species and corresponds to a finer level. Within a given native species, the genetic origin of the plant individuals can be taken into account to favour local geographical plant individuals among the native species. This approach can reinforce ecological issues at developed sites and promote local plant production approaches. Two labels were thus proposed in France.

b. Plant height, corresponding to different layers of vegetation

Depending on their growth form, plants will form various vegetation structures, which can be characterized by layers. Four main layers can be distinguished, which will have environmental consequences (ecological habitats, aesthetic characteristics...): tree layer, shrub layer, herbaceous layer and moss or ground layer (Braun Blanquet 1965).

c. Selection of introduced plant / Plants to avoid or that can be limited

- *Invasive alien species*

They are plants that have been introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment. They are species that sustain self-replacing populations over several life cycles; produce reproductive offspring, often in very large numbers at considerable distances from the parent and/or site of introduction; and have the potential to spread over long distances

Ludwiga peploides
(Source: Tela Botanica)

Cortaderia selloana
(source: Tela Botanica)

Illustration of invasive alien species in Europe

- *Allergenic species*

Definition: Plants that emit substances (pollen…) that can cause an allergic reaction in humans.
Illustration : French aerobiology network (RNSA) (http://www.pollens.fr/en/)

- *Other criteria: toxic, urticate plants, etc.*

These plants can cause damages to humans according to others criteria. Depending on the uses, some plants can be avoided as toxic plants, urticate...

There are also proposals for classifying plants according to their emission of VOC (for example for trees: hppts://www.selectree.calpoly.edu)

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development 07| Public Health and well-being > 07-2 Quality of life > 07-3 Health	- Increasing biodiversity - Contributing to preserve ecological continuities - Providing a habitat for birds and insects, and other animals - Anticipating eco-management - Developing resilience of green spaces - Aesthetic value - Contact with nature - Support for education - Avoiding allergies
Co-benefits and challenges foreseen	01| Climate Issues > 01-2 Climate adaptation 2| Water Management	- Different vegetation layers helps reducing heat stress
Possible negative effects	07| Public Health and well-being > 07-3 Health	- Presence of undesired insects - Presence of weeds

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: a building, a wall, a place, a green space. The quarter: diversity of plants for example can be done at the quarter scale in order to diversify ecological habitats (forests, open herbaceous areas, …) The city: planning of green infrastructures
Impacted scales	The 3 scales are impacted Regional scale is also impacted when ecological connectivity is ensured
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Immediately if the pre-existent vegetation is conserved. Long term if a forest is expected.
Life time	The life time depends on the renewal time of the plantations. Itself depends on plant species (2-25 years): - 1-10 years for the herbaceous plants - 4-10 years for the shrubs 10-25 years for trees (it is quite short for trees, but the life expectancy is strongly reduced in the unfriendly urban environment)
Sustainability and life cycle	It depends on plant species. - At the city scale, plantations are more resilient to changes. The complementary of plants of different origin and with different features ensure sustainability.
Management aspects (kind of interventions + intensity)	- Control of vegetation development. - Realizing new plantations
II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Users of public areas - Municipality
Technical stakeholder's networks	- Landscape architects - Landscape planners at the city scale - Specialized green spaces management firms, horticulturist and gardeners. - Naturalists' NGO - horticultural producers
Social aspects	Environmental education, Awareness campaign, training, participatory process, nature conservation Cultural aspects of plantations
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	**Plant choice criteria** These skills concern cultivated plants: - Selection of plant adapted to: • the local climate • the exposition • the soil • challenges targeted • the traffic intensity (the level of perturbation) - Chose the support system well adapted to the plant and to place where vegetation grows - Vegetation management - Botanical skills

	Landscape architecture and landscape - Aesthetic expectations (colour, form of foliage, period of flowering/fructification, foliage persistence etc.) - The way plants take part in specific uses (shadow, visual mask, physical separation), etc. **Plant supply** - *Horticulture* A large palette of plants can be produced by cultivation. For the 'non-invasive species", see the definition below. - *Ecological restoration techniques (ex.: collect of seeds in natural environment)* Some plants are not traditionally cultivated. But their seeds can be collected in the natural environment. It is for example the case of herbaceous plants. This technique is often used in ecological restoration. In this case, it is necessary to respect local law that preserve natural areas.
Materials involved	- Seeds or plants - Adapted substrate - Maps of ecological habitats

II.5 Legal aspects related	
Invasive plants (List of plants established by IUCN, www.griis.org) Protected plants (The IUCN Red List of threatened species, www.iucnredlist.org), refer to national laws	
II.6 Funding Economical aspects	
Range of cost	Very variable depending on the situation and the type of plants. However, some principles can be identified: 1°/Seedling and the choice of young plants is more economical 2°/ preserve existing vegetation is a main to save money
Origin of the funds (public, private, public-private, other)	- Depending of the owner
II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)	
- Every NBS using alive vegetation	

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Ecological and botanical knowledge and awareness of landscape architects and urban green spaces mangers (it is very variable following actors) - Cooperation been landscape architects with different sensibility: for example for designing the green skyline in NY, James Corner (Landscape architect and project manager leader) called in Piet Oudolf (a garden designer with deep knowledge in botany) for the planting design.
Limiting factors	- The availability and diversity of plants in horticultural trade (Bergues 2010) - The constrains of the urban ecosystem in dense city that limit the palette to fewer plants - Habits/ "traditions" in landscape architecture (for example: monospecific street tree)

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- See factsheets of the different NBS using vegetation Urban vegetation with poor diversity is more sensitive to pests and diseases. It implies more intensive management and often-chemical treatments.
Close NBS	- See factsheet “Choice of plants > Use of pre-existing vegetation” - See factsheet “Choice of plants > Vegetation diversification” - See factsheets of the different NBS using vegetation

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Cousins, S. H. (1991). Species diversity measurement: choosing the right index. Trends in Ecology & Evolution, 6(6), 190-192.

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. Ecology, 54(2), 427-432.

Kohsaka, R., Pereira, H. M., Elmqvist, T., Chan, L., Moreno-Peñaranda, R., Morimoto, Y., ... & Cruz, C. S. (2013). Indicators for management of urban biodiversity and ecosystem services: City Biodiversity Index. In Urbanization, biodiversity and ecosystem services: challenges and opportunities (pp. 699-718). Springer Netherlands.

Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography, 21(5), 545-555.

Invasive Alien Species in Europe (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)

French aerobiology network (http://www.pollens.fr/en/)

List of plants established by IUCN, www.griis.org

IUCN, the red List of threatened species, www.iucnredlist.org

UFEI - SelecTree: A Tree Selection Guide: hppts://www.selectree.calpoly.edu

Trees in Hard Landscape – A guide for delivery. 2014. Trees and Design Action Group.

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Florgård, Clas. « Long-term changes in indigenous vegetation preserved in urban areas ». Landscape and Urban Planning 52,(2): 101 16

Bergues, Martine. 2010. “Fleurs jardinières et fleurs fleuristes.” *Ethnologie française* 40 (4): 649–56. https://doi.org/10.3917/ethn.104.0649.

Hitchmough, James. 2011. “Exotic Plants and Plantings in the Sustainable, Designed Urban Landscape.” *Landscape and Urban Planning at 100* 100 (4): 380–82. https://doi.org/10.1016/j.landurbplan.2011.02.017.

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> VEGETATION DIVERSIFICATION

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS is based on a diversification of vegetation. The plant species diversity refers to: - Species richness: the number of different species represented in an ecological community, landscape or region. It does not take into account the abundances of the species. - Ecological diversity gives an idea of the biodiversity in an ecological community, integrating the number of different species (species richness) and the distribution of individuals within these species (abundances or densities). The vegetation diversification" gives elements for improving ecological diversity within the NBS. This species diversity also contributes to higher ecosystem resilience.

Different variants existing

This plant diversity can be considered and designed at different levels:

- **The species level**

Importance to privilege a large palette of species in planting design.

Several species
(Photo: Hervé Daniel)

Only one dominant species
(Photo: Hervé Daniel)

Comparison of two hedges

- **Indigenous species of local origin (Genetic plant population level)**

Another approach can still be added for the choice of species and corresponds to a finer level. Within a given native species, the genetic origin of the plant individuals can be taken into account to favour local geographical plant individuals among the native species. This approach can reinforce ecological issues at developed sites and promote local plant production approaches. Two labels were thus proposed in France

- **Vegetation layer diversity**

Depending on their growth form, plants will form various vegetation structures, which can be characterized by layers. Four main layers can be distinguished: tree layer, shrub layer, herbaceous layer and moss or ground layer (Braun Blanquet 1965).

This is an important factor for the structuring of ecological habitats, and for faunal biodiversity.

Monospecific lawns
(Source: Stephano Ferrario, Creative commons)

Multistrate space with flowery meadow
(Source: Josiane Gaillat, Wikimedia commons)

Monospecific lawns v/s multistrate space with flowery meadow

- **Diversity at larger spatial scales**

Diversity should not only be considered and designed at the scale of each NBS but also between NBS. In ecological sciences, this corresponds to "beta diversity", which makes it possible to evaluate the degree of originality of the NBS, i.e. the diversity between the NBS of the same city or the same district.
There are several local solutions to promote biodiversity. However, it is important to be able to vary these solutions to promote diversity at the district or city level.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 07| Public Health and well-being >7.2 Quality of life	- Increasing biodiversity - Providing a habitat for birds and insects, and other animals - Limiting risks of pest and disease in green spaces - Aesthetic and cultural value - Contact with a rich and diverse nature - Support for education
Co-benefits and challenges foreseen	05| Urban Regeneration and soil > 5.1 Soil Management and quality	- A diversity of plant also benefit to soil fauna biodiversity
Possible negative effects	07| Public Health and well-being > 7.3 Health	- Presence of undesired insects - Presence of weeds - Allergies

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The vegetation diversity can be thought at: - An object scale: a building, a wall, a place, a green space. - A quarter scale: diversity of plants for example can be done at the quarter scale in order to diversify ecological habitats (forests, open herbaceous areas, …) The city: planning of green infrastructures by the municipalities
Impacted scales	The 3 scales of implementation can be impacted. Regional scale is also impacted when ecological connectivity is ensured

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	• Immediately if the pre-existent vegetation is conserved. • Mid long term, when a diverse vegetation is installed in the frame of a project, this one requires time to be fully integrated in the ecological functioning. • Long term if a forest is expected because of the time growth of plants.
Life time	The life time depends on the renewal time of the plantations. Itself depends on plant species (2-25 years): - 1-10 years for the herbaceous plants - 4-10 years for the shrubs - 10-25 years for trees (it is quite short for trees, but the life expectancy is strongly reduced in the unfriendly urban environment)
Sustainability and life cycle	It depends on plant species. - A diversity of plant is a key factor for developing a complex and functioning ecosystem. It limits the pest and disease problems. - At the city scale, plantations are more resilient to changes.
Management aspects (kind of interventions + intensity)	Control of vegetation development. Examples: - No or limited irrigation for rustic species… - Different types of urban green spaces management… - Green roofs, vertical structures, parks and gardens….
II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Users of public areas - Municipality
Technical stakeholders networks	- Landscape architects - Landscape planners at the city scale - Specialized green spaces management firms, horticulturist and gardeners. - Naturalists' NGO - Horticultural producers
Social aspects	Environmental education, Awareness campaign, training, nature conservation Cultural added value
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition • the soil • challenges targeted • the traffic intensity (the level of perturbation) • interspecific competition (with other plant in the same place) - Chose the support system well adapted to the plant and to place where vegetation grows - Vegetation management - Botanical skills - Landscape architecture and landscape planning skills
Materials involved	- Seeds or plants - Adapted substrate - Maps of ecological habitat
II.5 Legal aspects related	
The diversification of vegetation cannot be done at whatever conditions: Invasive plants (List of plants established by IUCN, www.griis.org) Protected plants (The IUCN Red List of threatened species, www.iucnredlist.org), refer to national laws	

II.6 Funding Economical aspects	
Range of cost	Very variable depending on the situation and the type of plants. However, some principles can be identified: 1°/Seedling and the choice of young plants is more economical 2°/ preserve existing vegetation is a main to save money
Origin of the funds (public, private, public-private, other)	- Depending of the owner

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- Every NBS using alive vegetation

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Ecological and botanical knowledge and awareness of landscape architects and urban green spaces mangers (it is very variable following actors) - Cooperation been landscape architects with different sensibility: for example for designing the green skyline in NY, James Corner (Landscape architect and project manager leader) called in Piet Oudolf (a garden designer with deep knowledge in botany) for the planting design.
Limiting factors	- The availability and diversity of plants in horticultural trade (Bergues 2010) - The constrains of the urban ecosystem in dense city that limit the palette to fewer plants - Habits/ "traditions" in landscape architecture (for example: monospecific street tree)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Urban vegetation with poor diversity is more sensitive to pests and diseases. It implies more intensive management and often-chemical treatments.
Close NBS	- See factsheet "Choice of plants > Use of pre-existing vegetation" - See factsheet "Choice of plants > Introduced plants" - See factsheets of the different NBS using vegetation

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Cousins, S. H. (1991). Species diversity measurement: choosing the right index. *Trends in Ecology & Evolution*, *6*(6), 190-192.

Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, *54*(2), 427-432.

Kohsaka, R., Pereira, H. M., Elmqvist, T., Chan, L., Moreno-Peñaranda, R., Morimoto, Y., ... & Cruz, C. S. (2013). Indicators for management of urban biodiversity and ecosystem services: City Biodiversity Index. In *Urbanization, biodiversity and ecosystem services: challenges and opportunities* (pp. 699-718). Springer Netherlands.

Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. *Global Ecology and Biogeography*, *21*(5), 545-555.

Invasive Alien Species in Europe (http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)

French aerobiology network (http://www.pollens.fr/en/)

List of plants established by IUCN, www.griis.org

The IUCN Red List of threatened species, www.iucnredlist.org

IV.1 Scientific and more operational references (presented jointly)

UFEI - SelecTree: A Tree Selection Guide: hppts://www.selectree.calpoly.edu

Trees in Hard Landscape – A guide for delivery. 2014. Trees and Design Action Group.

IV.2 Sources used in this factsheet

Bergues, Martine. 2010. “Fleurs jardinières et fleurs fleuristes.” *Ethnologie française* 40 (4): 649–56. https://doi.org/10.3917/ethn.104.0649.

Hitchmough, James. 2011. “Exotic Plants and Plantings in the Sustainable, Designed Urban Landscape.” *Landscape and Urban Planning at 100* 100 (4): 380–82. https://doi.org/10.1016/j.landurbplan.2011.02.017.

Socolar, Jacob B., James J. Gilroy, William E. Kunin, et David P. Edwards. « How Should Beta-Diversity Inform Biodiversity Conservation? » Trends in Ecology & Evolution 31, no 1 (janvier 2016): 67 80. https://doi.org/10.1016/j.tree.2015.11.005.

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- **On the ground**
- **System for erosion control**

> **SOIL & SLOPE REVEGETATION**

> **STRONG SLOPE REVEGETATION**

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	**Stabilizing exposed soils on slopes through revegetation in order to minimize or prevent the erosion of soil by wind or rain and sedimentation problems**  An urban environment slope revegetated and protected with a coir mat © Aussie Erosion When land is disturbed at a construction site, or the natural vegetation cover is retired, the erosion rate may increase significantly. Proper planning and use of erosion control prevention and mitigation measures can reduce the impact of human-caused erosion. A well-established vegetative cover is one of the most effective methods of reducing erosion. Vegetation protects soil surfaces from rain generated splash erosion and can help slow runoff flows across a site of ground disturbance. In addition, plants establish root systems, which stabilize soil and prevents soil erosion against weathering forces. Even though mud, dirt and sand are natural, they are still serious pollutants that must be prevented from entering the waterways, including the storm water drainage systems, which discharge to creeks, waterways, rivers and beaches. That is why this vegetation coverture should be established on construction sites as soon as the slopes are finished. The four most common soil erosion prevention methods through revegetation are: • Stabilizing slope soil by hydro-seeding, • Erosion control mat, • Covering with mulch, • Surface roughening

Different variants existing

=> Stabilizing exposed soils by hydro-seeding

Control of erosion and soil management on natural slopes or embankments and cut slope (on construction sites)

The most common way to stablish a vegetal coverture is by seeding. The goal of the erosion control by seeding is to have a rapid establishment and a dense fibrous root system.

- **Hydroseeding**: is an alternative to the traditional process of broadcasting or sowing dry seed. It is very effective for hillsides and sloping lawns to help with erosion control and quick planting. Water, seed, fertilizer and protective mulch is mixed in a tank and sprayed onto the ground (3).

Embankment hydroseeded in Madrid-Galicia high-speed railway
© Acciona I+d+i

- **Seeds selection**. Seed mixes are developed for specific climatic zones to match the optimum growing conditions for each species.

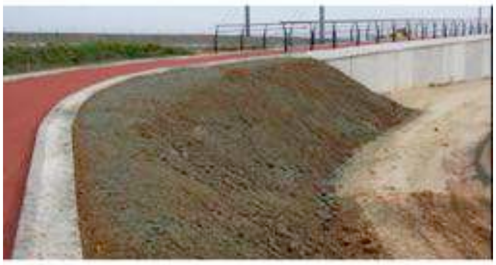
Another plant characteristic of importance is how the grass develops, grows and spreads (for instance rhizomatous grass that send out runners that will start new growth). Rooting depth is important, the mixture of rooting depths provides optimum support for soils and best enables the removal of water by the roots at the various zones in the soil. Seed used in a hydroseeder does not need to be any specific ones. Nearly any seed can be used and at the same application rate as other seeding methods.

- **Water** in the mix acts as a carrier and the contact of the seed and the water will jump-start the growth process. When extra fast germination is desired, it is also possible to pre-germinate seed for even faster growth.

- **Fertilizer** is usually used in the mix. A high phosphorus "starter" fertilizer that will stimulate root growth is the most commonly used.

- **Mulch**. Fiber mulch accelerates the growing process by maintaining moisture around the seeds thereby increasing the rate of germination (1).

- **Other additives**. Other products that may be added to a hydro seeding mix are products called tackifiers (guar gum and copolymers) acting like a glue to hold mulch in place that help hold the materials on a hillside in rainy conditions. The site also determines some additives as can be a lime based product added if the pH needs correcting. Other products such as co-polymers that hold 400 times their weight in water and slowly release it as the moisture is needed, or growth stimulants or symbiotic mycorrhizas, etc.



Hydro seeding restauration in L'Horta, Spain
© Acciona Ingeniería S.A.

=> Covering with mulch

Mulch is a name given to a group of organic and inorganic materials (such as decaying leaves, bark, or compost) that are spread on the soil surface to prevent the erosion of soil by wind or rain. These plant based materials are usually considered temporary and are intended to degrade after the establishment of permanent vegetation.

Applying a layer of mulch to the soil top protects it against rain impact and allows the soil to slowly soak up water. It can encourage seeds to sprout and protect seedlings and thus helping with erosion prevention.

The biggest limitation for use it in embankments and cuttings is that it is unstable with high slopes, needing the combination with other techniques such as cells.

Straw and wood fibres (wood chips) are the most common materials applied as loose mulch. Straw mulch can be used as light mulch (wheat or oat straw). Wood chip mulches are useful for weed control. Typical ground covers such as grass have difficulty growing through heavy woody material because of its weight and also as this high-carbon material decomposes, it removes plant nutrients from the soil (through microbial processes), resulting in low soil fertility (4). Application of a nitrogen rich fertilizer maybe required. Nevertheless, bark chips mulch does not require additional nitrogen fertilizer but it has to be considered that pine barks reduce the PH of soil, so should not be used on low PH soils.

- Minimizes erosion by providing a protective cover over disturbed, bare, reseeded or revegetated soils
- Minimal thickness protects soils form splash erosion while thicker layers are effective for additional sediment control.
- Protect seeds and seedlings favouring the cover of the soil with vegetation and avoiding erosion
- Heavy mulch reduces weeds by preventing germination of weed seeds
- Retains moisture by reducing evaporation, thereby reducing the need for watering
- Last but not least, a mulched surface looks much better than bare soil

Bark mulch and Mypex slope
©Lynch garden design

=> Erosion control blankets, (ECBs) or mats

Erosion control blankets are mats comprised of 100% organic fibers (biodegradable). ECBs are used to stabilize disturbed surfaces and to promote the establishment of vegetation. There are two main types of erosion control mats; jute mat and coir mat. With these natural fibers can be weaved an open geotextile.

There is another type of mat or a composite geotextile incorporating UV-sensitive netting for improved short-term stability..

Straw blanket with synthetic netting
© Titan

Using these mats like an erosion control tool is an effective method because it holds the root of vegetation and stabilizes soil. When used in conjunction with growing vegetation, it is even more effective.

The key to successful revegetation is good soil condition, good surface preparation and intimate contact between the blanket and the soil. (5)

When vegetated, it has the mechanical strength necessary to hold soil in place and prevent erosion. The netting breaks up runoff from heavy rains and dissipates the energy of flowing water and wind. Mesh promotes the growth of new vegetation by absorbing water and preventing the topsoil from drying out.

Natural fiber mesh together with revegetation
© Fullservice Green solutions

- Prevent erosion from exposed soils on slopes with medium runoff
- Typically used when a vegetative cover cannot be achieved due to soils, time of year or where slopes are too steep for mulch.
- Mats can be biodegradable (organic material) or ultraviolet degradable (synthetic material) and have different grades for different duration of protection, ranging from 2 months to 36 months
- Synthetic reinforcing net can entrap wildlife such as lizards, snakes and birds

Placement of an coir mesh
© Aussie Erosion

=> Surface Roughening

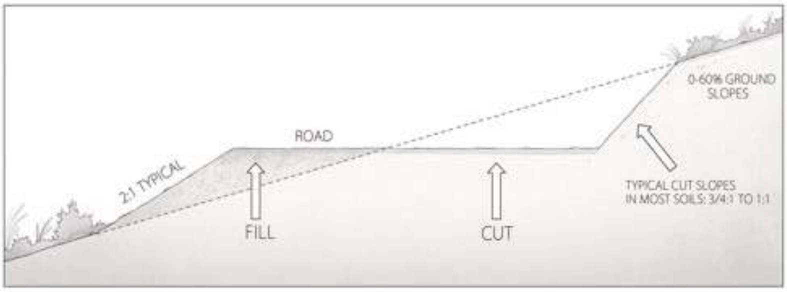
Surface roughening is a temporary erosion control practice where the soil surface is roughened by the creation of grooves, depressions, or steps that run parallel to the contour. It can also be used to help establish vegetative cover by reducing runoff velocity and giving seed an opportunity to take hold and grow by reducing runoff velocity and allowing soil infiltration and acting as a sediment trap.

Surface roughening

© Massachusetts Department of Environmental Protection

However, this practice alone is not sufficient to stabilize a slope for long periods, that is why it is normally used in combination with other erosion control measures such as mulching and seeding or planting. Roughening alone as an erosion control measure is of limited effectiveness in intense rainfall events. If roughening effects are washed away in a heavy storm, the surface will have to be roughened again and new seed and mulch applied.

Roughening methods may include tilling, disking or harrowing, which must be done across the slope along the contour. Tracking, by contrast, must be done up and down the slope. The main factor to choose one method or the other depends on the origin of the slope; cut slope or fill slope.



Examples of fill slope and cut slope

© Noah Kroese/2014/08/

- **Fill slopes** roughening (7)

Fill slopes are not as stable as cut slopes, no matter how much compaction is applied. Therefore, slopes which are steeper than 3:1 (H:V) should be avoided.
Use grooving or tracking to roughen the face of the slopes as necessary. Operate tracked machinery up and down the slope to leave horizontal depressions in the soil.
Apply fertilizer, mulch, or other soil amendments as necessary prior to grooving or tracking. Do not blade or scrape the final slope face. Seed and mulch roughened areas to obtain optimum seed germination and growth. (7)

- **Cut slopes** roughening (7)

Cut Slopes are much more stable than fill ones.
Consider the use of steeped slopes or terraced slopes.
Tilling, disking, and harrowing are also acceptable methods of roughening a cut slope. Groove the slope using machinery to create a series of ridges and depressions that run across the slope and on the contour.
Excessive roughness is undesirable where mowing is planned.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water Management > 02.-1 Water management 04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 05| Soil management > 05-1 soil management and quality	- Avoiding water system drainage problems due to the accumulation of eroded sediments. Intercept rainwater. - Soil conservation promotes vegetation growth, provides habitat for insects and animals and in consequence biodiversity - Avoiding soil erosion and the loose of its potential productivity
Co-benefits and challenges foreseen	01| Climate issues > 01-2 Climate adaptation 07| Public Health and well-being > 07-2 Quality of life 10| People security > 10.2 Control of extraordinary events.	- Contribute to urban heat island mitigation. - Aesthetic value. A poorly managed and eroded soil is always unsightly. - Vegetated slopes are more stables against landslides after heavy rains.
Possible negative effects	07| Public Health and well-being 04| Urban space management	- It could become a shelter for undesired and unhealthy animals. - There is more fire risk during dry seasons that is why these surfaces require the maintenance of these green areas, which implies more costs.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	- Private houses, - Public residential areas - Building construction sites for commercial or industrial areas planned for development or redevelopment, - Cut or fill embankments on infrastructure construction sites
Impacted scales	Neighbourhoods
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	It is usually the time to establish permanent, stabilizing vegetation and depends of types of the selected plants: - Grass: it takes about three months, - Shrubs: 1 to 2 years - Trees: 2 to 3 years
Life time (5)	- Vegetation; from 12 months to 20 years - Light Mulch: no longer than 1 year - Heavy Mulch: from 1 to 2 years - Erosion control blankets: from some months to 3 years - Soil roughening: few months
Sustainability and life cycle	- Plants and light mulch can be composting or recycling in most of the cases. - Erosion control blankets finish degraded naturally after few years. - Heavy mulch is a natural product that can be revalorized to fuel or reuse it.
Management aspects (kind of	- Stabilize disturbed slopes as quickly as possible. - Any necessary maintenance and repair must be made prior to leaving the site.

interventions + intensity)	- once finished the work and after few months, review the slope situation to ensure that erosion and sediment control measures are in working order - Check the irrigation system once per year - 1-2 vegetation maintenance interventions per year.

II.3 Stakeholders involved

Stakeholders involved in the decision process	- Owners, co-owners of infrastructure or construction site - Municipality (in case of municipal properties) - Private owners, eventually an isolated neighbour
Technical stakeholders & networks	- Soil scientist - Landscape architects - Irrigation system designers - Specialized green spaces management firms and gardeners.
Social aspects	- Raise awareness among private owners that stabilizing slopes is necessary to avoid erosion problems. - Revegetated slopes implies more aftercare although it is more pleasant

II.4 Design / techniques/ strategy

Knowledge and know-how involved Or key points for success	- Geotechnics knowledges, - Designers of environmental corrective measures			
Materials involved	**Hydroseeding** - Seed selection - Water - Fertilizer - Mulch Tackifiers - Hydro-seeding-pump	**Mulch** - Light mulch: straw from wheat or oat - Heavy mulch: wood chips + nitrogen fertilizer Or pine barks - Selected plants - Irrigation system	**ECBs** - 100% biodegradable mesh: Jute fiber or coir fiber - Composite geotextile: - Retaining pins - Selected mix of plants - Irrigation system	**Soil roughening** - Machinery - Selected mix of plants

II.5 Legal aspects related

It is illegal for any substance other than rainwater to enter the storm water system. Soil can damage storm water drainage system and damage the environment, so private owners, builders or developers are subject to control this kind of erosion problems.
Company's inability to manage a construction site correctly can cause fines (even his disqualification), the same as for private owners damaging storm water drainage.

II.6 Funding Economical aspects

Range of cost (Prices are from Spain 2016 and it must be considered the scale impact on prices. These are prices for big works not for private plot works)	**Hydro-seeding** 1,66 €/m^2	**Heavy Mulch, supply and implementation** Pine barks (35€/m^3): 5 €/m^2 Wood chips: 9 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average	**ECBs, supply and implementation** Coir fibre mesh (350g/m^2): 5 €/m^2 Jute fibre mesh: 3 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average	**Soil roughening implementation** 0,7 €/m^2 Selected plants: (4 perennials and 1 sap tree): 40 €/m^2 average
Origin of the funds (public, private, public-private, other)	- Private land owners or co-owners - Infrastructure manager - City councils - Construction companies			

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

=>.Rock mulch together with wood fiber mulch:

Cost: gravel mulch (5 cm height) over anti-weed mat (5,22€/m^2)

© Lawn-wranglers.com

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors-

- Choose the correct NBS based on the slope gradient, soil characteristics, local climate conditions and final expected aspect,
- Choose a mixture of plants adapted to the local environment,
- Good soil surface preparation,
- Mulch is unstable with high slopes,
- Blanket Correct installation making sure the blanket is flush with the soil surface.
- Set up the maintenance keeping plants in the right conditions

Limiting factors	- Steep of the slope - The type of soil (organic material, PH, texture etc.) - Geotechnical soil conditions (fill or cutting slope) - Soil water availability - Pest - Fire risk

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart	**=>.Retaining walls** Slope can be stabilized with retaining walls. Traditional retaining walls can be made out of corrugated steel sheet-pile, steel gabion baskets filled with rock, articulated cement blocks, polyethylene geocells, cut stone, brick, timber or even geofoam.

Anchor Highland Wall - Bull Run
© Allied concrete

Gabions used as soil retainer on a sloping soil surface
© gabion1.com.au

=>.Rock mulch:

There are many different types of rock to use as mulch. Rock mulch is heavier to handle and apply than bark mulch. It is also a more permanent landscape installation, not decomposing into the soil or adding organic matter. Nevertheless, it requires a weed barrier underneath to keep weeds from growing up through the rock layer and more expensive to install.

Rock mulch used as soil retainer
© Bistrodre.com

Close NBS	**=> Slope revegetation Steeper than 2:1** **=> Soil structuration**

IV/ References

IV.1 Scientific and more operational references (presented jointly)

1. West, Dawn (2006-08-21). "Planting by Hydroseeding". All About Lawns. Retrieved 2013-05-14.
2. Cook, Owen (2016-05-04). "Lawncare via. Hydroseeding". Tampa Landscaping. Retrieved 2016-05-04.
3. California Department of Transportation (CalTrans). Sacramento, CA. "Construction Site Best Management Practices (BMP) Manual." Section 3, BMP No. SS-4. March 2003.
4. Babcock D. and McLaughlin R. (2008) “Mulch Options for Erosion Control on Construction Sites”. North Carolina State University. http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-67W/
5. “Erosion control blankets”(2010) Catchments & Creeks Pty Ltd
6. Massachusetts Department of Environmental Protection, Office of Watershed Management, “Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas”, Boston, Massachusetts. June, 1993.
7. Knoxville BMP Manual Erosion & Sediment. (2001) www.knoxvilletn.gov/engineering/

IV.2 Sources used in this factsheet

- A. Janet Aird (2008) Hydroseeding Tips and Techniques From the Pros. www.erosioncontrol.com
- http://furbishco.com/ SmartSlope: Vegetated Retaining Wall | Smart Design
- Erosion Prevention and Sediment Control Planning and Design Manual. Oregon City Addendum to Clackamas County
- http://soilerosiononline.com/article-permalink-426.html
- Catchment & Creeks Pty Ltd. “Erosion control Blankets factsheet”. IECA International Erosion Control association. July 2010

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STRONG SLOPE REVEGETATION
(Steeper than 2:1)

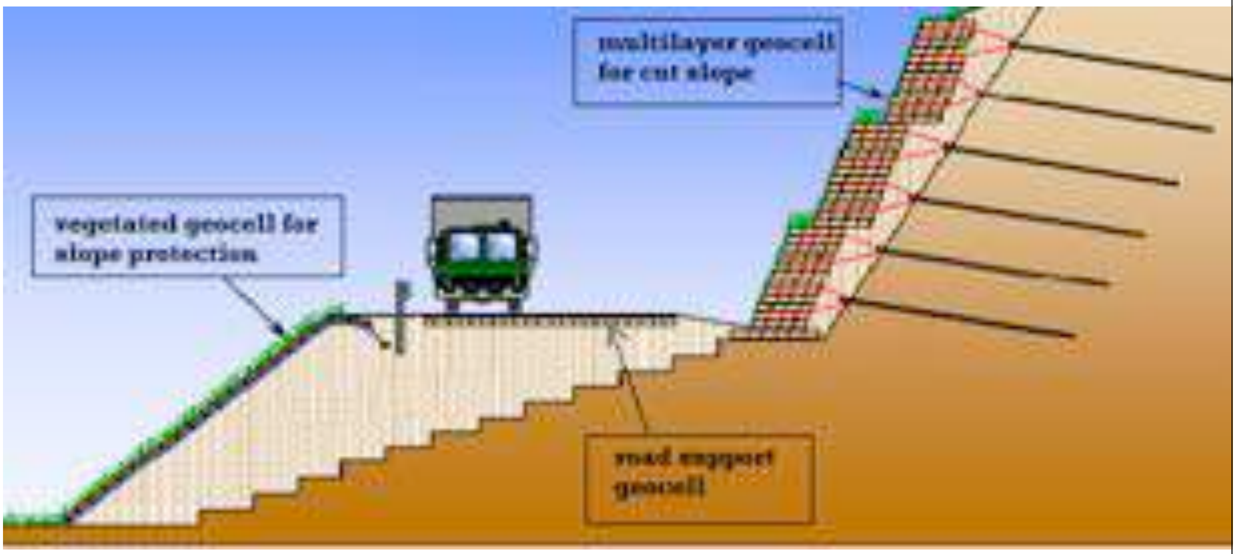
I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	• **Stabilizing soils structure on steepened slopes through revegetation in order to minimize or prevent the erosion of soil by wind or rain and landslides, avoiding sedimentation problems**  **Smart slope-vegetated-retaining-wall, Dakota. Furbish 2013.** © United Themes. When the slope is really steeped, the most common slope stabilization and erosion prevention method is some kind of retaining slopes method joined with revegetation. The origin of unstable slopes can be natural because of the soil geotechnical properties, or as consequence of human activities that create new cutting slopes or embankments during construction works. When soil is disturbed at a construction site, or the natural vegetation cover is retired, the erosion rate may increase significantly. Proper planning and use of erosion control prevention and mitigation measures can reduce the impact of human-caused erosion. In order to stabilize steepened slopes, some kind of soil retention method is nevertheless needed; joining it with a well-established vegetative cover is one of the most effective methods of reducing erosion in unstable slopes steeper than 2H:1V. The retention method keeps the soil meanwhile vegetation protects soil surfaces from rain generated splash erosion and can help to slow runoff flows across a disturbed ground.

In addition, plant roots hold their soil in place, keeping it from washing away during rainstorms. Lastly, trees help to prevent high winds from blowing away top soil because the trees provide windbreaks, which can prevent high winds.
Vegetation should be established on the slopes as soon as possible when the construction works are finished.
In the urban environment, even though mud, dirt and sand are natural they are still serious pollutants that must be prevented from entering the waterways, including the storm water drainage systems, which discharge to creeks, waterways, rivers and beaches.
There are two main variants for the stabilization of steeped slopes and its revegetation:

- Reinforced soil slopes (RSS) with cellular confinement systems (CCS)
- Mechanically Stabilized Earth Wall (MSE):
    - Multilayer geocell
    - Concrete blocks
    - Gabions

In general, MSE walls are distinguished from reinforced soil slopes (RSS) by the inclination of the facing:
• Reinforced soil slopes are inclined flatter than 70 degrees from horizontal.
• MSE walls are inclined steeper than 70 degrees from horizontal. (7. TAC 2017)



Multilayer geocell earths retention wall schema
© Geoweb

Different variants existing

=>. Reinforced soil slopes with cellular confinement systems (CCS) (also known as geocells) and revegetation

Vegetated geocell for slope protection

Geocell is a honeycombing interconnected cellular confinement system. It is made out of high-strength polyethylene or other plastic, and can be green in and of itself. Some geocell is made from recycled plastic and is recyclable again at the end of its useful life.
“It has been observed that ‘Geocells’ significantly enhances the load-bearing capacity of soils and reduces settlement of the concern geotechnical structure”. (1)
This geocellular containment system provides a cost effective solution for the reinforcement of cuttings and embankments, preventing slope failure and soil loss.

- 3D structure reinforces the upper soil layer and resists erosive conditions and sliding forces beyond limits of other systems. Long-term solution for sustainable vegetation, permeable aggregate or geomembrane protection.
- Reduces land space requirements and costs by allowing slopes to be designed steeper than when unconfined.

Each open cell is also permeated with slots, to allow quick threading of root tendrils. The lifespan of CCS in slope protection applications is less critical as vegetative growth and root interlock stabilize the soil. This in effect compensates for any long-term loss of confinement in the CCS.

Sections of geocell are shipped flat. When you pull open a panel and reveal its 3-D structure, it looks something like a honeycomb. Once the geocell installed, their cells are filled with soil. When the wall is all covered it's finally hydroseeded or revegetated.
"The use of Geocell for erosion control applications eliminates complicated and expensive construction techniques. Geocells 3D structure provides a blanket of 'cells' on the slope surface which can be in-filled with a variety of materials depending on the application, This improves resistance to erosive forces such as rainwater run-off on steep or unstable slopes" (2).

Geocells folded up for transportation and storage
© Henfengsuye

A slope covered with geocell and infilled with topsoil
© Terram geosynthetics

A slope covered with geocell
© Alpha Pinnacle

The same slope once vegetation has grown
© Alpha Pinnacle

=> Mechanically Stabilized Earth Wall (MSEW) (earth retention), or Vegetated retaining wall.

MSEW stabilizes unstable slopes and retains the soil on steep slopes. The wall face is often of precast, segmental blocks, panels or geocells that can tolerate some differential movements. The walls are infilled with granular soil, with or without reinforcement, while retaining the backfill soil. They serve a vital purpose in construction and erosion control, bearing loads and holding slopes back from sliding down, but sometimes they are not the nicest things to look at.
Nevertheless, vegetated retaining walls fulfil their primary load bearing or erosion-prevention purpose, but with an extra, environmentally beneficial aesthetics.
Reinforced walls utilize horizontal layers typically of cell walls, articulate concrete walls or gabions. The reinforced soil mass, along with the facing, forms the wall. In many types of MSE's, each precast row provides individual cells that can be infilled with topsoil and planted with vegetation to create a green wall.

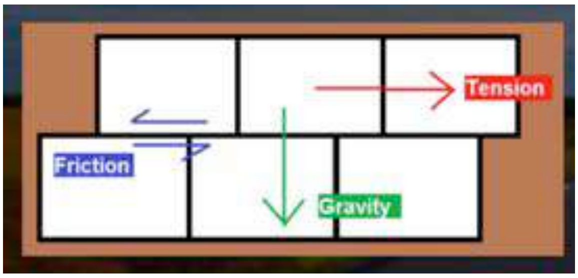
- **Cell walls**

Cells walls check the runoff streams associated with rainfall, keeping the overall system intact. The infill material also rests within individual cells, allowing for much higher angles of Cells grid filled with soil promotes vegetation as both another source of reinforcement and natural aesthetics. Overall effectiveness of the system is increased with the plant roots integrated into the grid system.

Geocells are manufactured in different deeps and cell sizes. One of its advantages is that it is easily installed without specialized equipment or crews.

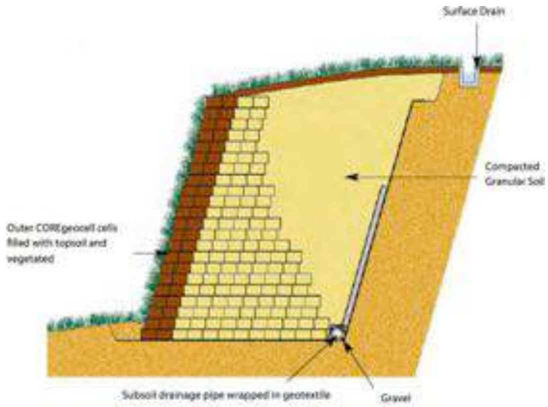
Multilayer geocell slope retention system
© GEOWEB

Stabilizing Forces: Interlocking cells provide tension and Increased friction surface between layers creates resistance



Forces' stabilization between Geocells
© JANELLE KATHRYN.P.ONG.

Walls with Natural Vegetation
© GEOWEB



Geocell wall construction's schema
© Aldi Helme Egland UNDERyourfeet

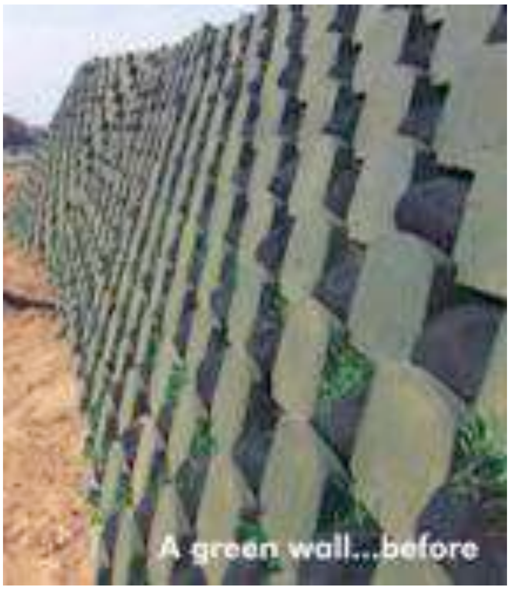
- **Articulated Concrete blocks**

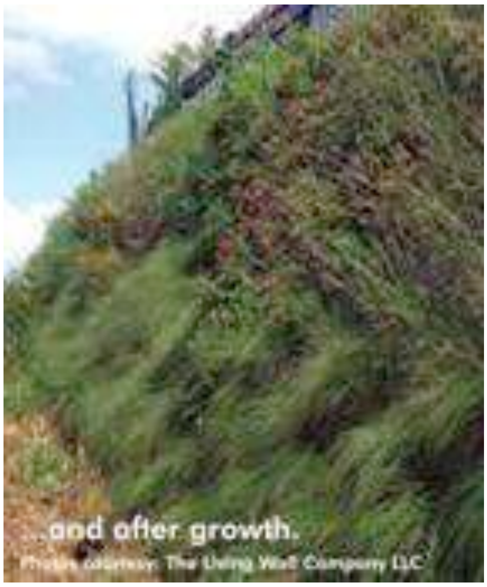
The retaining wall face is built interlocking cast blocks used as a face wall connected to mechanical reinforcement (metal smooth or ribbed steel bars or geosynthetic fabric; linear, grids or mats etc.).

Concrete can be vegetated. Several manufacturers make cast concrete blocks with pockets that can be filled with growth media. Then pockets are planted. The entire face of the wall will be covered with vegetation upon grow out.

Articulated concrete wall
© Furbish.co

Vegetated concrete wall
© Simpson Gumpertz & Heger





Soil erosion and hydroseeding (soilerosiononline.com)

- **Gabions**

A gabion is usually a cage, cylinder, or box filled with rocks, concrete, sometimes sand and soil for use in civil engineering, road building, military applications and landscaping. Gabions became very popular because they can be stacked vertically and they look like more natural than concrete blocks.

Vegetated gabions still fulfil their primary load bearing or erosion-prevention purpose, but with an extra, environmentally beneficial flourish, “On the top, it can be planted jasmine or any other type of vining plant. The vines will eventually drape over the wall and weave in and out of these crab traps (gabions). The mesh (openings) is about the same size as those found in chain link fencing, perfect for ‘weaving’ plants.”

Advantage of gabion baskets:

- Their porosity. If there is one thing that’s the enemy of retaining walls, it is water. Gabions filled with broken or crushed stone have built-in drainage.
- Their flexibility. Subjected to alternating forces of tension and compression, the inherent flexibility of a gabion structure enables it to deform rather than break.

 © Dong Xue	 © Fengxiang Hardware Limited

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality > 02-1 Urban water management 04| Biodiversity and urban space > 04-1 | Biodiversity 05| Soil management > 05-1 | soil management and quality 10| People security > 10.2 | Control of extraordinary events	- Avoiding storm water system drainage problems due to the accumulation of eroded sediments, - Vegetated slopes promote vegetation growth, provide habitat for insects and animals and in consequence biodiversity - Avoiding soil erosion and problems with slope stability and sediments dispersion - A well-stabilized slope avoids the risk of landslides and the damage to people and their properties. - Slope stabilizing methods preserve the integrity of soil structure to minimize impacts face to stronger storms or higher rain frequency
Co-benefits and challenges foreseen	01| Climate issues > 01-1 | Climate adaptation 07| Public Health and well-being > 07-2 Quality of life	-Create vegetation wall that favour climate adaptation - Aesthetic value. A poorly managed and eroded slope is always unsightly.
Possible negative effects	07| Public Health and well-being 04| Urban space management	- It could become a shelter for undesired and unhealthy animals. - There is more fire risks during the dry season that is why these surfaces require a urban space management that is expensive. - Vegetated slope requires the allocation of their management costs

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	- Cut or fill embankments at infrastructure works - Building construction sites and neighbourhoods. - Private backyards - Riversides
Impacted scales	- Neighbourhoods - Private plots - Watershed
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	The wall is effective against erosion since its construction is finished. The establishment of vegetation improves its efficiency against erosion. Its establishment depends on types of the selected plants: - Grass: it takes about three months, - Shrubs: 1 to 2 years - Trees: 2 to 3 years
Life time	20 years or more
Sustainability and life cycle	- Plants can be composted or recycled in most of the cases. - Geocell can be made from recycled plastic and is recyclable again at the end of its useful life. Nevertheless, polyethylene does not decompose naturally. - Concrete blocks can be revalorized once chopped for other construction ends - From gabions, stones can be reuse and metal is sold and revalorized for reuse too.
Management aspects (kind of interventions + intensity)	- Contractor should check the stability of overall structure, once finished the works - Once past few months since the completion of the work, It should be checked the correct drainage function and its stability - Periodic reviews of its stability after heavy rains - Check the irrigation system once per year - 1-2 vegetation maintenance interventions per year.
II.3 Stakeholders involved	
Stakeholders involved in the decision process	- Owners, co-owners of infrastructure - eventually neighbour or municipality (in case of municipal plots) - Private owners - Geotechnical engineer - Wall contractor
Technical stakeholders (6)	- the owner and his/her representative; - geotechnical engineer; - civil engineer; - structural engineer; - general contractor; - wall contractor; - wall manufacturer; and - Landscape engineers, architects - Specialized green spaces management firms and gardeners.
Social aspects	- Raise awareness among private owners that MSEW needs the supervision of a geotechnical or structural technician. - Revegetated slopes implies more aftercare although it is more pleasant

II.4 Design / techniques/ strategy

Knowledge and how-know involved Or key points for success	- Geotechnical structure knowledges - Follow the soil backfill parameters on the engineering drawings (without fine soil particles) - Drainage requirements, avoiding to saturate the retaining soil - Responsibility for stability checks - Selection of vegetation adapted to: • the local climate • the exposition of the slope • Low soil water storage • Fire risk • challenges targeted • the traffic intensity (the level of pollution) - Set up the maintenance keeping plants in the right conditions.
Materials involved	For all the NBS here described: - Heavy machinery - Specialise crew Specific materials for each NBS here described:

Vegetated geocell	Vegetated retained wall of concrete walls	Vegetated retained wall of gabions
- Geocell matrix - Tendons - Anchors - Drain - Infill: topsoil and fill soil - Mix of seeds	- Concrete blocs - Drains - Infill: topsoil and fill soil - Mix of seeds and plants	- Gabions - Infill: topsoil and fill soil - Mix of plants

II.5 Legal aspects related

Constructor responsibility for the wall stability.
It is illegal for any substance other than rainwater to enter the storm water system. Soil can damage storm water drainage system and damage the environment

II.6 Funding Economical aspects

	Vegetated geocell	Vegetated retained wall of concrete walls	Vegetated retained wall of gabions
Range of cost	m^2 Supply and installation Geocell matrix, including anchoring: - 18 mm: 15,25 €/m^2 - 20 mm: 17 €/m^2 - 10 mm: 10,51 €/m^2 - Supply and installation Drain 110 mm: 3,74 €/m - Infill: topsoil: 12 €/m^3 - fill soil: 1,03 €/m^3 - Mix of seeds: 1,66 €/m^2	- m^2 retained wall of Concrete blocks: 73 €/m^2 - Supply and installation Drain 110 mm diameter: 3,74€/m - Infill: topsoil: 12 €/m^3 - fill soil: 1,03 €/m^3 - Mix of seeds and plants: 17 €/m^2	- m^3 retained wall of Gabions: 99€/m^3 - Infill: topsoil: 12 €/m^3 - fill soil: 1,03 €/m^3 - Mix of climbing plants (*Hedera helix, Jasminum ssp, Solanum jasmioides*): 15 €/m^2
Origin of the funds (public, private, public-private, other)	- Private land owner - Infrastructure manager - Private companies plot owners. - City councils		

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

It is possible to have two different slope gradients on the same surface that requires different solution designs, combining erosion control solutions specific for overstep slope and for slopes flatter than 2:1.

Mulch technics combined with concrete blocks on the same slope surface
© Furbish

Geocell wall combined with a fiber mat on the same slope surface
© Furbish

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors

Geocell (4)

- Good surface preparation with the removal of all major surface irregularities
- Where necessary (a slope steeper than 10%) establish up-slope drainage controls to limit run-on water
- Expand and stretch the panels down the slope instead of across the slope
- The mesh needs to be well anchored if placed on a concave surface or on slopes steeper than 10% using J-pins at 2m down the slope,
- Fill the geocell mechanically or manually and such that when compacted, the fill will be level with the upper surface of the panel

MSE walls (MSE are geotechnical structures)

- Analyse working stresses
- Selection of reinforcement location and check that soil mass and reinforcement stresses are OK
- Evaluate stability at each reinforcement level
- Check stability of overall structure; external, internal and combined

Plants selection

- Select native plants in order to reduce maintenance
- Select drought tolerant plants in arid areas (avoiding irrigations problems with the slope stability)

Limiting factors	**Soil slope** - Soil slope flatter than 70 degrees: Reinforced soil slopes (RSS) with cellular confinement systems (CCS). - Soil slope steeper than 70 degrees: MSE walls are inclined steeper than 70 degrees from horizontal. (7. TAC 2017) **MSE** - Water must be controlled such that entry into the MSE wall system is minimized. When it does enter the soil mass, it needs to be collected and diverted away from the wall.

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Traditional retaining walls can be made out of corrugated steel sheet pile, steel gabion baskets filled with rock, articulated cement blocks, cut stone, brick, or even geofoam, without any vegetation.
 Brick structure © Allied concrete	 Gabions © gabion1.com.au
Close NBS	=> Slope revegetation (Flatter than 2:1) => Soil structuration

IV/ References

IV.1 Scientific and more operational references (presented jointly)

1. Biswas, A. & Krishna, A.M. Int. J. of Geosynth and Ground Eng. (2017) 3: 17. https://doi.org/10.1007/s40891-017-0093-7

2. Srinivas Angadi. (2017) "Role of geosynthetics in civil engineering" presentation

3. JANELLEKATHRYN.P.ONG. (2015). "Geocells". In the website: www.emaze.com/@ALWCTTIL

4. Catchment & Creeks Pty Ltd. (2010) "Cellular confinement system". Website of IECA International Erosion Control association.

5. The Transportation Association of Canada. 2017 "Mechanically Stabilized Earth Walls". In the website www.tac-atc.ca/sites/default/files/site/doc/Bookstore/mse-primer2017.pdf

6. Strohman, Bryan P. and DiFiore, Scott J. (2013)"Mechanically stabilized earth walls" . In the website www.constructionspecifier.com

IV.2 Sources used in this factsheet

- http://furbishco.com/ SmartSlope: Vegetated Retaining Wall | Smart Design
- Erosion Prevention and Sediment Control Planning and Design Manual. Oregon City Addendum to Clackamas County. In the website www.clackamas.us/wes
- http://soilerosiononline.com/article-permalink-426.html
- http://www.abg-geosynthetics.com/

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➢ On the ground

➢ Works on Soil

> MULCHING

> SOIL IMPROVMENT

> STRUCTURAL SOIL

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

Mulching is a technique used in plantations and maintenance that consists in covering the surface of the soil with an organic, mineral or plastic material in a continuous (film) or discontinuous way (grains, fragments, etc.) to protect the ground and plants mainly against weeds and soil evaporation. Originally, the term was created in 1935 to designate the action of mulching the soil (Loreau, 2014). In addition, mulching is one promising technology that is an integral component of conservation farming and is increasingly seen in the light of integrated soil management—an essential building stone for sustainable agriculture. The use of mulch has great agro-ecological potential—it typically conserves the soil, improves the soil ecology, stabilizes and enhances crop yield and provides various environmental services (Erenstein, 2003).

Wood chip mulch
© ETFN Bois Energie

Different variants existing

Two kinds can be identified, depending of the botanical properties:

=> Non-living mulching (organic and inorganic)

Non-living mulch is applied over the soil surface to suppress weed seed germination by the exclusion of light and to act as a barrier that will physically prevent weed emergence. Mulches may be composed of natural materials of organic or inorganic origin or synthetic materials that have been manufactured specifically for this purpose or which are recycled products. They may take the form of flat sheets that are laid by hand or machine, or loose particles that are spread out to form a continuous layer (Grundy and Bond, 2007).

Non-living mulches provide a number of benefits. These include retention of soil moisture, prevention of leaching, improved soil structure, disease and pest control, improved crop quality and, in many crops, extended growing season that reaps financial rewards. However, the primary advantages are associated with weed control (Abul-Soud et al., 2010; Grundy and Bond, 2007).

Are there different types of non-living mulching? It is possible to cite:

- Sheeted mulches: this type of solution includes black polythene sheeting, clear polythene sheeting, coloured polythene sheeting, geotextiles, needle-punched fabrics, paper mulches, newspapers and carpet.
- Particle mulches: this type of solution includes shredded and chipped bark or wood mulch, finer particles of wood, crushed rock or gravel mulch, straw and hay, grass clippings, crop wastes, industrial waste materials (Gill et al., 2011).

 In permaculture, sheet mulching is often done near the house to prepare a kitchen garden © Smiling garden	 Mulch using Pozzolana, Mayenne, France 2013 © Plante & Cité – Andréa Loreau
 Mulch using tree bark or particles of wood, Mayenne, France 2013 © Plante & Cité – André Loreau	 Needle punched week barrier © Landscape Fabric Factory

=> Living mulching (cover crop)
Living mulches are cover crops planted either before or with a main crop and maintained as a living ground cover throughout the growing season. If the living mulch is perennial, it may be possible to maintain it from year to year without the need for reseeding (Hartwig, 1987).The next year's crop is planted into the suppressed cover crop usually by some no- or minimum tillage method (Hartwig and Ammon, 2002).
Cropping systems with the use of ground covers have been worked out for vineyards, orchards, and common agronomic crops, such as corn, small grains, and forages. Legume cover crops have the potential for fixing nitrogen, a portion of which will be available for high-nitrogen-requiring crops such as corn (Hooda et al., 1998).

 Cabbage grown in the green zone of manure © Image by apichsn	 Tree Well with Fine Fescue as a Living Mulch © Gail Langellotto, Oregon State University

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity > 04-2 Urban space development and regeneration 05| Soil Management > 05-1 Soil management and quality 06| Resource efficiency > 06-1 Food, energy and water > 06-3 Waste > 06-4 Recycling	- Provide habitat for insect and birds - Gas exchange: the O_2 content decreases while the CO_2 content increases. Mulching improves the soil structure and thus allows better gas exchange (Loreau, 2014) - With the continuous presence of cover crops, surface water runoff is greatly reduced and the loss of nutrients and pesticides by this route are almost totally eliminated (Rüttimann, 2001) - Protect the soil from the impact of rain (Danso et al., 1991; Loreau, 2014). - Reduce the vertical moisture gradient in the soil due to evaporation (Loreau, 2014). - Fight against wind erosion; - With the positive results in vineyards, trials with living mulches in fruit production also have intensified (Gut et al., 1996) - Mulch usually use recycle materials
Co-benefits and challenges foreseen	02| Water Management and quality > 02-2 Urban water management > 02-2 Flood management	- Reduce evaporation: mulching limits the action of wind and sun by creating a break in continuity hydraulic between the ground and the atmosphere (Loreau, 2014). - Reduce, water needs - Create a surface roughness that slows the flow of and reduces runoff (Loreau, 2014).
Possible negative effects	02| Urban Water Quality > 02-1 Urban water management 04| Biodiversity and urban space > 04-1 Biodiversity 05| Soil Management > 05-1 Soil management and quality 06| Resource efficiency > 06-1 Food, energy and water	- Increased runoff and increased erosion in impermeable mulches. - Mulching stifles plants that come out of the soil if the mulch is too close to the collar (point of separation between the stem and the roots of a plant). - Mulching does not bring organic amendment and it can bring unwanted chemicals (Loreau, 2014). - Fuel consumption for cutting and transporting wood until exploitation.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: roundabout, building, single tree, parkway, garden
Impacted scales	The scales impacted are in most of case extended. It concerns the plot of the building itself
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Few months after adding mulch. For example, Fall is the best time to install mulch. The main objective is to protect soil and plant from Winter.
Life time	The lifetime of mulch depends on climate conditions, type and its use. For example: • Mulch fabric (90 g m^{-2}) has a lifespan of about 5 years while the 130g m^{-2} mulch fabric has a lifespan of about 10 years. • Inorganic mulch has a time life greater than 10 years (Loreau, 2014) • Prefabricated materials: 4 to 6 years of life • Raw organic mulch: 1 year of life • Wood mulch: 3 to 4 years
Sustainability and life cycle	- Urban soil can be mulched using organic and inorganic mulch (eliminate weeds and need little maintenance) - Organic mulch requires interventions (additions). Synthetic mulch must be removed. Moreover, the soil and plants on it can be composting or recycling in most of the cases.
Management aspects (kind of interventions + intensity)	Three times a year (Fall, Spring and Summer): • Fall is the best time to install mulch. This one will indeed make it possible to protect perennials from the winter rigors, while respecting the cycle of the nature. An organic mulch of plant origin will decompose during the winter to feed the soil and provide the soil with all the nutrients it needs. • Spring, it is therefore recommended to remove the mulch around the feet of the plants to avoid the proliferation of parasites. • Summer, to compensate for the lack of moisture, it is strongly recommended to lightly rake the mulch, to promote the infiltration of the water from watering or rain, in the ground.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Municipality is a main stakeholder in public gardens, roundabout, squares, streets and limits of properties
Technical stakeholders & networks	- Specialized green spaces management firms, horticulturist and gardeners.
Social aspects	- because of the potential negative aspect of the mulch techniques, it is needed o find an agreement with all the stakeholders involved in the area to applied it=> importance of the participatory process.

II.4 Design / techniques/ strategy

Knowledge and -know- how involved	- Knowledge about soil properties as PH, soil nutrients, local weather, aesthetics landscaping
Materials involved	• Mineral mulch: sand, pozzolana, gravel, slate • Prefabricated materials: clay, crushed glass, crushed brick, products based on recycled rubber • Raw organic mulch: flax flakes, hay, hemp glitter • Wood mulch: maritime pine bark, wood chips, wood pellets, bagasse, fragmented rameal wood, non-composted wood mulch from Landes pine. miscanthus fiber

II.5 Legal aspects related

All materials (mineral, organic and non-organic matter) should respect environmental and agronomic standards established by each country.

II.6 Funding Economical aspects

Range of cost	The price of this NBS depends on the type of mulching. In general, price of mulch is comprised between 0.75 to 2 €/m^2 (material prices and installation cost) (Link)
Origin of the funds (public, private, public-private, other)	- Mainly public - If the plot owner is private, the fund must be private

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

There a various way to combine mulching solution with other NBS types.

- It is possible to combine green roof solution and mulching.

Implementation of hay mulching on green roof Installation in Kirkland, WA, USA © Bark King

- Use Pozzolana or compost of vegetable waste to protect and to ornament private garden.

 Mulching using Pozzolana © JBEEDISGNERS Outdoor	 Mulching compost of vegetable waste © AHS Property Care & Landscape Supply

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors- mulching quality and
- The right mulch at the right place (for example, relation with the soil, plant and period of implantation)

Limiting factors	- Soil pH can be a limiting factor for some kind of mulch - Pest can be a limiting factor in some environments

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart	• Reduction of diversity of plants • Zero vegetation when non-living mulching solution is used • Rock mulch with a weed barrier underneath to keep weeds from growing up through the rock layer.: • printed concrete surfaces  © Horizon driveways • paved surfaces

	 © Hub surface systems
Close NBS	**Structural soil, soil improvement, slope revegetation**

IV/ References

Nota: references presented below are often common with the whole category Works on soil "Soil improvement".

IV.1 Scientific and more operational references (presented jointly)

Abul-Soud, M., El-Ansary, D., Hussein, A., others, 2010. Effects of different cattle manure rates and mulching on weed control and growth and yield of squash. J. Appl. Sci. Res. 1379–1386.

Danso, S., Curbelo, S., others, 1991. Herbage yield and nitrogen-fixation in a triple-species mixed sward of white clover, lotus and fescue. Soil Biol. Biochem. 23, 65–70.

Erenstein, O., 2003. Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. Agric. Ecosyst. Environ. 100, 17–37. https://doi.org/10.1016/S0167-8809(03)00150-6

Gill, H.K., McSorley, R., Branham, M., 2011. Effect of Organic Mulches on Soil Surface Insects and Other Arthropods. Fla. Entomol. 94, 226–232. https://doi.org/10.1653/024.094.0215

Grundy, A., Bond, B., 2007. Use of non-living mulches for weed control. Non-Chem. Weed Manag. 135–153.

Gut, D., Holzgang, O., Gigon, A., 1996. Weed control methods to improve plant species richness in vineyards, in: Proceedings of the 2nd International Weed Control Congress. Slagelse, Denmark: Department of Weed Control and Pesticide Ecology Flakkebjerg. Google Scholar. pp. 987–992.

Hartwig, N., 1987. Cropping practices using crownvetch in conservation tillage.

Hartwig, N.L., Ammon, H.U., 2002. Cover crops and living mulches. Weed Sci. 50, 688–699.

Hooda, P., Moynagh, M., Svoboda, I., Anderson, H., 1998. A comparative study of nitrate leaching from intensively managed monoculture grass and grass–clover pastures. J. Agric. Sci. 131, 267–275.

Loreau, A., 2014. Diversité et effets du paillage (Fiche de synthèse). Plante & Cité.

Pascual, J., Garcia, C., Hernandez, T., Ayuso, M., 1997. Changes in the microbial activity of an arid soil amended with urban organic wastes. Biol. Fertil. Soils 24, 429–434.

Randrup, T.B., Dralle, K., 1997. Influence of planning and design on soil compaction in construction sites. Landsc. Urban Plan. 38, 87–92. https://doi.org/10.1016/S0169-2046(97)00024-8

Rüttimann, M.A., 2001. Boden-, Herbizid-und Nährstoffverluste durch Abschwemmung bei konservierender Bodenbearbeitung und Mulchsaat von Silomais: vier bodenschonende Anbauverfahren im Vergleich; mit 68 Tabellen. Wepf.

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

The soil improvement or fertility is not limited to its consistency as a medium of culture and its mineral content, but to a set of agricultural practices dependent on the environment and the choices of the farmer.
To maintain the performance of this environment, which seems to be the main source of food production, it is essential to supply all the physical, biological and chemical constituents (Huber and Schaub, 2011).
Increasing soil agronomic quality is also another way of soil improvement. This includes:
(i) integrating or improving nutrient management,
(ii) increasing carbon sequestration,
(iii) enhancing water infiltration,
(iv) ensuring water at the plant-root zone and
(v) encouraging beneficial soil organisms (Council et al., 2009).

Different variants existing

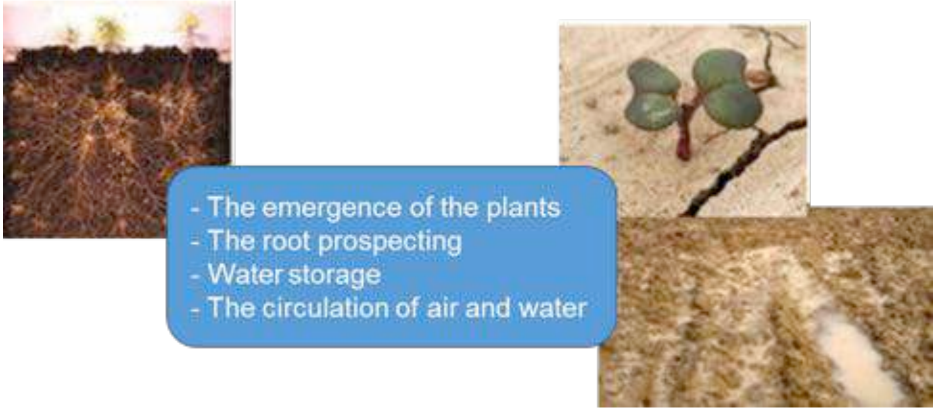
=> Physical soil improvement (physical soil fertility)

It is defined by the greater or lesser ability to create and maintain a physical state of the soil favourable to a cropping system (Monnier et al., 1982). The constituent elements of the "fine earth" fraction welded together by the humus, form aggregates, which form between them lacunary spaces filled with air and water. It is the clay-humic complex, which flocculated by the presence of calcium gives the soil a stable structure. In addition, the physical properties of soils are those that influence the following factors:

- Air circulation: without air in the soil, the roots do not breathe and the plant dies of asphyxiation. The lack of air results most often from excess water.
- Circulation and retention of water: water brings nutrients to the plant and the plant regulates its temperature by perspiration. The retention of water in the soil influences the leaching, the rate of infiltration, the rate of runoff
- The soil is more or less resistant to detachment; this property is called "erodibility". It is closely related to the structural stability of the soil, which is defined in detail below.

Several solutions exist :

- Implementing structural soil to avoid soil compaction (see NBS “structural soil”)
- Maintaining continued plant cover on land by using appropriate stocking rates,
- Deep ripping of compacted soils or layers,
- Retaining stubble and green manuring to increase organic content and reduce compaction and erosion,
- Applying gypsum on sodic soils.



Adapted from Mickaël GREVILLOT Chambre Départementale 70

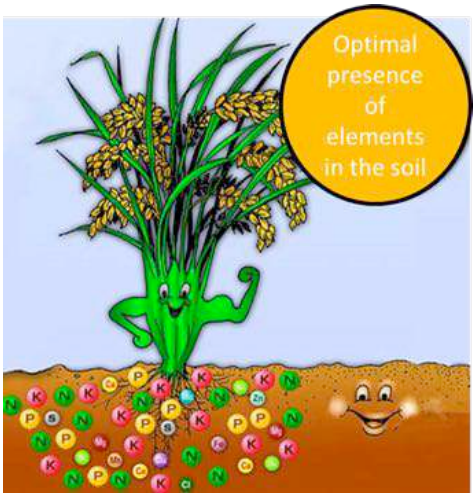
=> Chemical soil improvement

Chemical soil improvement relates to the mineral nutrition of plants through the concepts of bioavailability of elements, deficiencies, toxicities and balances. A balanced nutrition supposes that the plant finds (sufficient quantity) and can absorb (chemical equilibrium, favourable pH, availability of water to favour the absorption, mineralization of the organic matter ...) all the elements, which it needs. These different nutrients are present in various forms, and only a part is directly available by plants. In fact, the organic matter and the minerals of the soil must be transformed (respectively by mineralization and dissolution) so that their constituent elements are available by the plants.

Under no circumstances should one of these factors be neglected to obtain good quality soil. Fertility depends on environmental conditions (bedrock, nature of minerals, texture, climate ...), but also and above all the conduct of human activities, including agricultural and forestry practices.

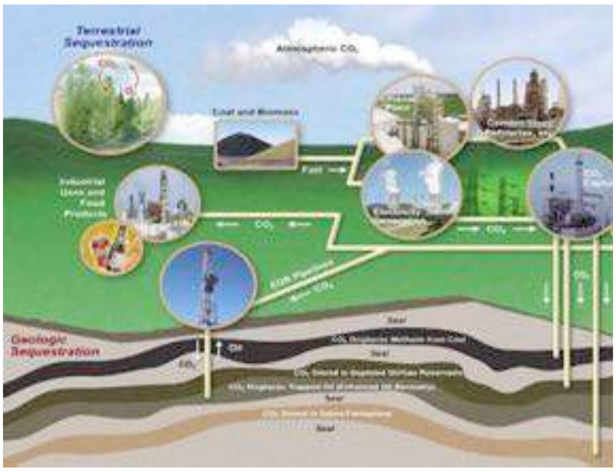
Several solutions exist :

- Organic matter (compost) amendment to ensure long-term nutrient storage for plants
- Mineral fertilizers to satisfy immediately plant nutrition
- Limestone amendment in acidic soils
- Leguminous specie plantation to favour nitrogen incorporation into the soil (symbiotic fixation)
- Bioremediation and phytoremediation to reduce chemical contaminants that are toxic for plants (see NBS " phytoremediation"



Plant Nutrition and required plant elements
© International Rice Research Institute

Turfgrass nutrient management
© Maryland Department of Agriculture

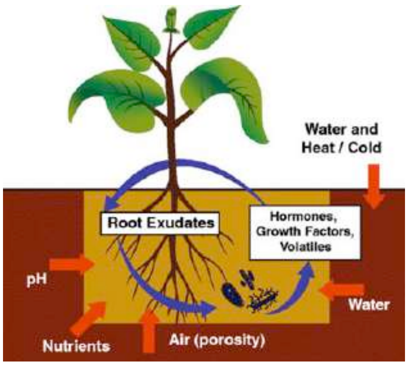


Urban carbon sequestion
© Richard Martin, WLRD Environmental Programs

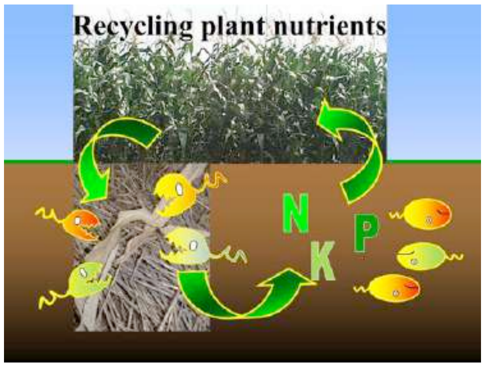
=> Biological soil improvement
Soil biological processes are extremely diverse and complex (Lavelle and Spain, 2001). This level of complexity constrains our ability to assess or predict the biological state of soil through measures of abundance of organisms or their activity (Pankhurst and Van Der Kraak, 1997). However, soil biological fertility can be named as: soil biological activity or soil biological health. All of those appellation can be defined as the capacity of organisms living in soil (microorganisms, fauna and roots) to contribute to the nutritional requirements of plants and foraging animals for productivity, reproduction and quality
(considered in terms of human and animal wellbeing) while maintaining biological processes that contribute positively to the physical and chemical state of soil (Abbott and Murphy, 2003).

Several solutions exist :

- Organic amendments and organic fertilizer that stimulate and increase the soil biological activity and diversity
- Plant mycorhization is possible for some plant species. It favours soil water and nutrient access by roots
- Avoiding pesticide use and preferring biological protection



Impact of microorganisms, fauna and roots on the fertility of soil
© (Chaparro et al., 2012)



The litter broken down, or decomposed, by soil microbes © Richard Stehouwer

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-2 Urban space development and regeneration 05| Soil Management > 05-1 Soil management and quality 06| Resource efficiency > 06-1 Food, energy water	-Sustainable management practices, ground cover, accessibility -Reduce the settlement of structures -Immobilise or stabilise contaminants in dredged soil in order to mitigate and preferably eliminate environmental impacts -Reduce soil contamination by dewatering and bearing capacity (immobilization). - Improve plant s' growth
Co-benefits and challenges foreseen	06| Resource efficiency > 06-1 Waste > 06-3 Waste > 06-4 Recycling 11| Green economy > 11-1 Circular economy	- Improve plant growth - Wastes generated by urban and industrial activities such as green wastes or sludge can be recycled and composted and used as organic amendment -Favours local economy by reducing transport costs and local waste use - Changing images of the urban environment
Possible negative effects	02| Urban Water Quality > 02-1 Urban water management 04| Biodiversity and urban space > 04-1 Biodiversity	- Soil amendments can alter the physical and chemical environment of soil organisms

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: roundabout, building, private garden The neighbourhood: parkway, public garden The city: shallow bay (Eid and Alansari, 2004)
Impacted scales	The scales impacted are in most of case extended. It concerns from the plot of the building itself to the city scale.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Soil physical and biological improvements can become nearly immediately. Soil chemical improvement such as bio/phytoremediation can take several years (5-10 years)
Life time	The lifetime of soil improvement depends on climate conditions and its use. For example, the service life of parkway and the roads is 20-50 years.
Sustainability and life cycle	- Urban soil can be amended using organic wastes (Pascual et al., 1997)
Management aspects (kind of interventions + intensity)	- Choosing mature compost to avoid rapid biodegradation and possible soil quality decrease, leaving crop residue, incorporation of cover crops in the rotation cycle, mulching with natural material and plastic, conservation tillage and no tilling, controlled grazing, improve pasture species, controlled use of irrigation

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - eventually neighbour or municipality (case of gardens, square on limits of property)
Technical stakeholders & networks	- Specialized green spaces management firms, horticulturist and gardeners.
Social aspects	- Necessity to find an agreement with all the co-owner of urban soil => importance of the participatory process. - Necessity to inform about the real impacts, to reassure about widespread prejudices (risk to use a polluted soil)

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Knowledge of the fundamental mechanisms will make it possible to control the conditions of re-use of fine soils in earthworks and thus open up prospects for use in parts of works that are now excluded, such as embankments in flood zones, embankments contiguous to hydraulic structures, railway layers. -Soil fertility: Do not cultivate your soil unless it is very compacted. Digging destroys the soil structure by reducing air pockets and drainage spaces which are both necessary in healthy soils - When watering use a trigger hose with a spray setting so as not to compact the soil as the water hits. The concentrated pressure of the water stream can close up valuable air spaces - Spreading compost and aged manure over your soil (before mulching) will encourage worms in your garden. - If you have clay soil, consider applying gypsum to break up the soil.
Materials involved	- Stones: chalcedony, pozzolana, hard limestone, etc. - - Soil (0-2 mm): topsoil from agricultural parcels (sanded down prior to an urban use conversion), or sub-soil. - Organic matter: green waste compost is one of the most used (important resource produced by all cities).

II.5 Legal aspects related

All materials (stones, soil and organic matter) should respect environmental and agronomic standards established by each country.

II.6 Funding Economical aspects

Range of cost

- The cost of soil improvement depends on lot of parameters:

- Fertilizer cost is the one of the biggest input cost for the soil study. Fertilizers are added to supplement nutrients that are naturally occurring in the soil. Nitrogen (N), Phosphorus (P) and Potassium (K) are the three major nutrients that are added in large quantities. Keep in mind that these figures vary throughout the year and are used only as examples

Single Nutrient fertilizer	Grade	Nutrient	% nutrient content	Cost €/ton fertilizer*
Urea	46-0-0	N	46	410
Anhydrous ammonia	82% N	N	82	637
UAN	28%	N	28	271
Triple super phosphate	0-46-0	P2O5	46	513
Muriate of potash	0-0-60	K2O	60	466

*Price per ton on February 17, 2011 from USDA reports

	• The cost of developing a vegetable maze would be 16 € / m². This cost includes: (i) Supply and earthwork of soil and silt (9€/m^3) and (ii) add organic amendment (6€/ton)
Origin of the funds (public, private, public-private, other)	- Mainly public

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- Soil improvement can serve the creation of gardens or urban orchards

Vegetable maze in the parc et l'îlot Rossini, Lille, France
© (Eva Lanxmeer)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors- Soil-stone quality and volume - The right plant at the right place (for example vigour in relation with the wall/building size)	
Limiting factors	- Soil load capacity may support almost 50 MPa - Tree growth capacity in such soils - Specialized green spaces management firms reliability
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Reduction of diversity of plants by using few organic amendments • Zero vegetation
Close NBS	**Structural soil, mulching**

IV/ References

Nota: references presented below are often common with the whole category Works on soil "Soil improvement".

IV.1 Scientific and more operational references (presented jointly)

Abbott, L.K., Murphy, D.V., 2003. Soil biological fertility: a key to sustainable land use in agriculture. Springer Science & Business Media.

Chaparro, J.M., Sheflin, A.M., Manter, D.K., Vivanco, J.M., 2012. Manipulating the soil microbiome to increase soil health and plant fertility. Biol. Fertil. Soils 48, 489–499. https://doi.org/10.1007/s00374-012-0691-4

Council, N.R., Division on Earth and Life Studies, Board on Agriculture and Natural Resources, Committee on a Study of Technologies to Benefit Farmers in Africa and South Asia, 2009. Emerging technologies to benefit farmers in sub-Saharan Africa and South Asia. National Academies Press.
Eid, H.T., Alansari, O.M., 2004. Large-scale land reclamation and soil improvement for a city expansion.
Huber, G., Schaub, C., 2011. La fertilité des sols: L’importance de la matière organique. Chamb. D’agriculture Bas-Rhin 46p.
Lavelle, P., Spain, A., 2001. Soil ecology. Springer Science & Business Media.
Monnier, G., Stengel, P., Guérif, J., 1982. Recherche de critères de la fertilité physique du sol et de son évolution en fonction du système de culture. Evol. Niv. Fertil. Sols Dans Différents Systèmes Cult. Critères Pour Mes. Cette Fertil. 1982 Sémin. CEE Agrimed Bari ITA 1981-09-28-1981-09-30 35-52.
Pankhurst, N., Van Der Kraak, G., 1997. Effects of stress on reproduction and growth of fish. Cambridge University Press Cambridge, UK.
Pascual, J., Garcia, C., Hernandez, T., Ayuso, M., 1997. Changes in the microbial activity of an arid soil amended with urban organic wastes. Biol. Fertil. Soils 24, 429–434.

Website
http://www.soilhealth.com/soils-are-alive/

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> STRUCTURAL SOIL

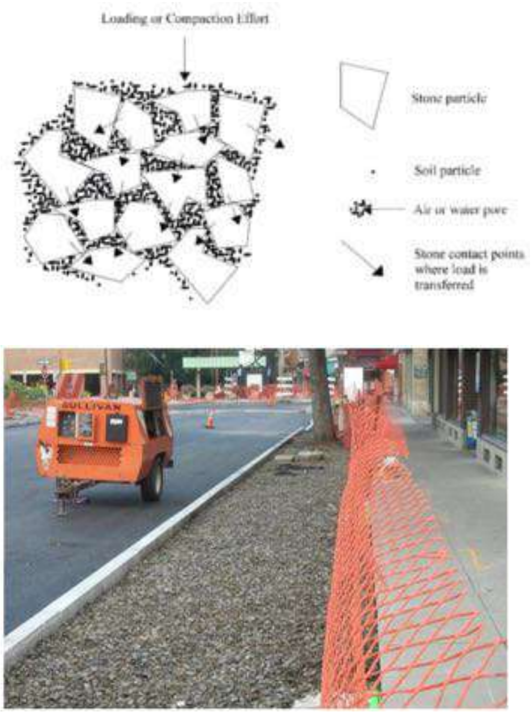
I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS aims to improve soil structure (also referred as skeleton, stony or engineering soils, depending on the literature). It is recognized as an alternative solution for preventing soil compaction in urban areas that limits root penetration and plant growth (Teymur and Atapek, 2010). These materials consist of mixes of mineral soil and aggregates (around 10-40 mm in size) originating from quarries. Such structural materials guarantee efficient water circulation, yet generally possess limited water availability for plant growth; they also favour root anchorage and the structural stability of trees.

Different variants existing

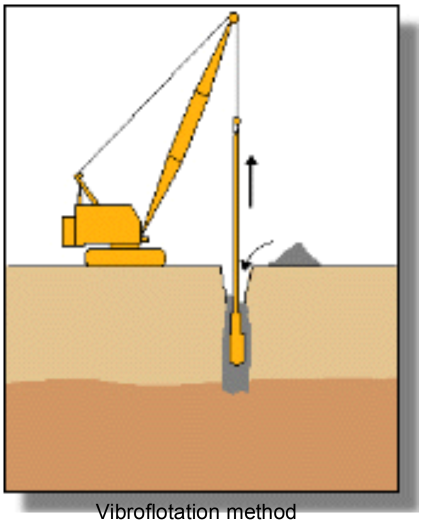
Ideal formulation of structural soils consists in stone soil ratio of 65:35% in volume. This is the best compromise for soil compaction resistance due to adequate stone skeleton and for soil agronomic purposes (water, air and nutrient supply). In addition, structural soil is one of the most economical engineering solutions to overcome many of soil problems. (Hashad and El-Mashad, 2014). There are various techniques to improve soil. It is possible to increase its physical structure using surface compaction, chemical stabilization, vibroflotation, and replacement of soil, drainage methods and vibration methods (Boyle et al., 2007).
Variants can exist, depending on the stone origin (see II.4)



Structural soil (Bassuk et al., 2015)

Structural soil profile (© Rossignol)

Rolling compaction
© Fujiroad



Vibroflotation method
© Hayward Baker, Inc., Odenton, Maryland.

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Urban Water Quality > 02-2 Flood management 05| Soil Management > 05-1 Soil management and quality	-Water infiltration decrease runoff, limiting flood risks - Reduce the shrinkage and swelling of soils
Co-benefits and challenges foreseen	01| Climate > 01-1 Climate mitigation > 01-2 Climate adaptation 06| Resource efficiency > 06-3 Waste > 06-4 Recycling 11| Green economy > 11-1 Circular economy	- A less compact favour root penetration and tree growth, and then evapotranspiration for an improved effect of urban heat island mitigation (Rahman et al., 2011) and carbon sequestration -Great possibility to use/recycle local inert wastes as stone materials or construction inert waste -Favours green economy by reducing transport and landfill cost using local stone and reusing inert construction waste
Possible negative effects	02| Urban Water Quality > 02-1 Urban water management 04| Biodiversity and urban space > 04-1 Biodiversity	-Introducing 65% of stone leads to decrease the soil water storage capacity and increasing water irrigation supply needs. -Plant species have to be chosen depending on stone nature (acidic or basic) - to improve soil, an injection of synthetic man-made materials, such as micro-fine cement, epoxy, acrylmide, phenoplasts, silicates, and polyurethane can cause the soil to become toxic (DeJong et al., 2010)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: tree plantation pit, road edges, roundabouts
Impacted scales	The scales impacted are in most of case limited. It concerns the plot of the building itself or the close neighbourhood.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	2-4 years => linked with the growth of plants Structural soils physical properties do not change along time. However, plants needs time to allow root system adaptation and development in the structural material volume.
Life time	Plant species concerned by this NBS are perennial ligneous plants: trees, shrubs. By contrast, to physical properties, chemical properties of structural materials should decline along time (ie nutrient content). To counterbalance this, high organic matter supply in the soil fraction should be high (almost 40% in volume) to favour long-term suitable properties. Then, the life time expected should be about 20-30 years
Management aspects (kind of interventions + intensity)	- Irrigation is necessary the first three years after plant installation. - Adventive plants should develop and may be eliminated. It is suggested to use a cover like gravels or porous asphalt for example to prevent such a development - Control runoff before it develops into an erosive force by using surface cover and trees - Avoid working with wet soils (always work with dry or moist soils, never with wet soils) - Limit travel routes and parking areas, Use lightweight vehicles (try to use only lightweight vehicles with large, smooth, low-pressure tires), - Soil mixing (compacted soil can be mixed with compost or a fully composted organic mulch to improve the soil quality, but up to 50 percent volume of soil is needed to make this technique useful).
II.3 Stakeholders involved	
Stakeholders involved in the decision process	- Municipality - Construction companies
Technical stakeholders & networks	- Geotechnical experts - Civil Engineering - Specialized green spaces management firms, horticulturist and gardeners.
Social aspects	-No necessity
II.4 Design / techniques/ strategy	
Knowledge and how-know involved Or key points for success	- Geotechnical knowledges -Stone characteristics : granulometry 40-90 mm, acidic vs calcareous stone and adequate plant species (calcifuge vs calcicolous plants) -Soil quality: should have adequate agronomic properties (texture, pH, no pollutants…) -Soil stone mixing, transport and installation under dry climatic conditions (irreversible soil compaction risk if soil water content high) -Structural material conservation: should be covered to avoid leaching and fermentation

	-Avoid impervious surface on the structural material to allow air and water exchange between the soil and the atmosphere - Stone characteristics: grain size of 50-100 mm, a compaction form when the bulk density is equal at 95% of the standard Proctor dry density (Roger, 1954)
Materials involved	-Stones: chalcedony, pozzolana, hard limestone… - Road sub-grade material: well graded, uniformity coefficient (D60/D10) should not be less than 3, fraction-passing sieve #200 shall not be greater than 2/3rd of the fraction-passing sieve #40. In coarse grain, aggregate retained by #10 sieve, %age of wear shall not be greater than 5%. -Soil (0-2 mm): topsoil from agricultural parcels (sanded down prior to an urban use conversion), or sub-soil. -Organic matter: green waste compost is one of the most used (important resource produced by all cities)

Arable soil
© Agrocampus Ouest

Green waste compost
© Agrocampus Ouest

Subgrade (existing soil) compacted by roller under road
© Jahangir Khan

Structural material with Pozzolana
© Agrocampus Ouest

II.5 Legal aspects related

All materials (stones, soil and organic matter) should respect environmental and agronomic standards established by each country.

II.6 Funding Economical aspects

Range of cost	Structural material cost ranges from 20 to 80 € / ton depending on the distance between the structural material storage and the settlement place in the city. For an individual plantation pit, it is recommended a volume of structural material of almost 10 m^3, corresponding to almost 6,3 tons
Origin of the funds (public, private, public-private, other)	- Mainly public

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- New /original wastes materials should appear in the future and could be suitable candidates for structural soil. However, it must be demonstrated that such materials do not present environmental risks

Structural materials: (on the left: excavation subsoil+concrete, on the right greenwaste compost+bricks)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	- Soil-stone quality and volume - The right plant at the right place (for example vigour in relation with the wall/building size)
Limiting factors	- Soil load capacity may support almost 50 MPa - Tree growth capacity in such soils - Specialized green spaces management firms reliability

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart	• Zero vegetation • Tree planting in pure soil The last solution will conduct to soil compaction, and tree root asphyxia and superficial root anchorage. The soil should be mixed with high amount of organic matter (up to 40% in volume), but soil natural compaction during the first 2 years is important and may counterbalance tree growth.
Close NBS	**Soil improvement**

IV/ References

Nota: references presented below are often common with the whole category Vertical structures "Structural soil".

IV.1 Scientific and more operational references (presented jointly)

Bartens J, Day SD, Harris JR, Wynn TM, Dove JE (2009) Transpiration and root development of urban trees in structural soil stormwater reservoirs. Environ Manage 44:646-657

Bartens J, Wiseman PE, Smiley ET (2010) Stability of landscape trees in engineered and conventional urban soil mixes. Urban Forestry & Urban Greening 9:333-338

Grabosky J, Haffner E, Bassuk N (2009) Plant available moisture in stone-soil media for use under pavement while allowing urban tree root growth. Arboriculture & Urban Forestry 35:271-278

Novak V, Knava K, Simunek J (2011) Determining the influence of stones on hydraulic conductivity of saturated soils using numerical method. Geoderma 161:177-181

Urban J (2013) Two different approaches to improve growing conditions for trees. Arboricultural Consultant 46:5-12

IV.2 Sources used in this factsheet

Bassuk N, Denig BR, Haffner T, Grabosky J, Trowbridge P (2015) CU-Structural Soil® A Comprehensive Guide. Urban Horticulture Institute, 57p.

Boyle, P., Ameratunga, J., De Bok, C., Tranberg, B., 2007. PLANNING FOR THE FUTURE-GROUND IMPROVEMENT TRIALS AT THE PORT OF BRISBANE. TERRA AQUA 108, 19.

Damas O., Coulon A. (2016). Créer des sols fertiles : du déchet à la végétalisation urbaine. Editions du Moniteur, Paris. In French

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Name	Institution / company	Writer/ reviewer
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➢ Water

➢ Natural and semi-natural water bodies and hydrographic network

> **REOPENED STREAM**

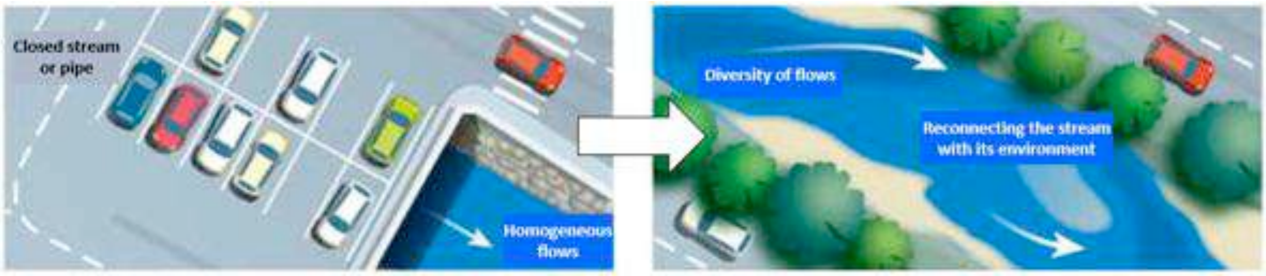
> **VEGETATION ENGINEERING SYSTEMS FOR RIVERBANKS EROSION CONTROL**

>

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	The complete coverage of a watercourse is undoubtedly the most traumatic human intervention that a river system can undergo since it results in the complete disappearance of the latter. It leads to the complete disappearance of the habitats, the riparian forest, the relations between the aquifer and the banks, etc., but also to a major ecological discontinuity of the fluvial network. Whenever the socio-political context allows it, the reopening of the stream should be realized. The opening of streams is necessarily accompanied by heavy demolition work and reconstruction of a new bed.

There are **different levels of restoration**:
1) The most radical method is to fully discover the watercourse and to "recreate" it completely in its natural thalweg respecting its original morphology
2) If the land area of the old route is not available, the watercourse can still be opened, and natural banks recreated (softening slopes, vegetation, etc.), with a low flow bed with a more adequate morphology
3) If, for various technical and financial reasons, discovering the stream is not possible, mitigation measures of the impacts can be implemented, such as the creation of wells of light on the covered linear (if it is not too long), the establishment of an alluvial substrate at the bottom of the bed, or the positioning of physical elements to facilitate fish movement.



Schematic representation of a reopened stream @ONEMA (adapted)

Some practical illustrations are provided below.

Before restoration (left image) – 6 months after restoration (right image)
© Photo: Vincent MIquel - CARG

Before restoration (left image) – 2 years after restoration (right image)
© SYMASOL

Before restoration in 1999 (top image) – After restoration in 2006 (bottom image)
© Photo Alain Cadou

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water management > 02-1 Urban water management and quality > 02-2 Flood management 04| Green Space and Biodiversity > 04-1 Biodiversity	- Improvement of the hydromorphological functioning of the watercourse - Potential improvement of flood control by improving stormwater management - Restore the aquatic habitats of the watercourse and increase the faunistic and floristic biodiversity - Ensure ecological continuity and improve the free movement of aquatic species
Co-benefits and challenges foreseen	01| Climate issues > 01-2 Climate adaptation 04| Green Space and Biodiversity > 04-2 Urban space development and regeneration 07| Public Health and Well-being > 07-1 Quality of life 09| Urban planning and governance	- Create cool areas - Enhance the landscape and recreational activities around and in the riverbed. - Revitalize the image of the river and offer residents a green space of quality - Diversify planning actions and stakeholders
Possible negative effects	07| Public Health and Well-being > 07-2 Health	-Possible pests such as mosquitos, frog cries…

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	In an anthropized sector, reopening a stream is often carried out on few linear meters (local scale).
Impacted scales	While the local ecological effect is appreciable, river-wide gains remain limited (more continuity has to be achieved to affect this scale).
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	The NBS is rapidly effective after its implementation: it only needs time for the reopened stream to stabilize and for the new vegetation to grow.
Life time	Life time of the stream
Sustainability and life cycle	A priori, no major impact associated with the life cycle of the NBS. The implementation phase is the phase most likely to generate impacts.
Management aspects (kind of interventions + intensity)	Occasional grass cutting
II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	Landowner (private or public)
Technical stakeholders & networks	Resort to a qualified contractor who has the needed equipment and experience is recommended.
Social aspects	No particular social bottleneck

II.4 Design / techniques/ strategy	
Knowledge and know-how involved **Or key points for success**	Reopening a stream necessary implies civil engineering works, e.g. for the removal of concrete slabs or flow nozzles.
Materials involved	Civil engineering machines are needed.

II.5 Legal aspects related
- In France, this type of action fits in the regulatory framework (*Déclaration d'intérêt general*, and/or *Dossier de demande d'autorisation au titre de la loi sur l'eau*). - Unlike other restoration measures, the reopening of watercourses requires land acquisition, a measure to be achieved or at least to be negotiated, from the preliminary study.

II.6 Funding Economical aspects	
Range of cost	Examples of streams reopening measures give cost ranges between 900 and 2500 € excluding VAT per linear meter (Eau Seine Normandie, 2007).
Origin of the funds (public, private, public-private, other)	Depending of the owner of the land (can be public or private).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Reopened streams can be associated with complementary measures, e.g. disconnecting the rainwater and / or wastewater systems, creating a fording in an agricultural area, modifying the geometry of the streambed, vegetating the riverbanks or planting aquatic and semi-aquatic plants.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Watercourse covering has very often disturbed the behaviour of the groundwater table, especially if it has been accompanied by piping, concreting of the bottom of the bed, deepening of the water lines, etc. Opening the watercourse must often be accompanied by a guarantee of tightness of the newly created bed, to avoid permanent losses of the watercourse after restoration works (by checking the natural bedrock (marls, clays, etc.) or, if necessary, by creating an artificial sealing under the new bed).
Limiting factors	- The coverage of a watercourse has often been linked to the urbanization of the areas initially occupied by the alluvial space or, in rural areas, to the more intensive use of these surfaces. This coverage has often been coupled with the "linearization" of the course of the watercourse as well as the "land consolidation" that accompanies it. As a result, opening a watercourse is inevitably a difficult restoration operation and a long-term "technical-administrative" procedure to put in place. It must necessarily be accompanied by the acquisition of land areas sufficient to restore the fluvial space. In addition, the initial route may often no longer be possible due to urbanization. - Putting under pipe or covering a watercourse is regularly coupled with a deepening of the stream, to favor its use as sewerage system. This deepening is sometimes very difficult, even impossible to recover, which then requires the realization of a watercourse "artificially" deeper than what would recommend the inspiration of natural models. - The water flow of the reopened stream must be sufficient

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	No alternative grey solution.
Close NBS	• Remeander rivers • Excavation of new waterbodies (ponds, lakes) • Infrastructures removed on rivers (ex. dams)

IV/ References

IV.1 Scientific and more operational references (presented jointly)

- RiverWiki is an interactive source of information on river restoration schemes from around Europe (up to now, 1026 river restoration case studies from 31 countries): https://restorerivers.eu/

IV.2 Sources used in this factsheet

- Eau Seine Normandie, Manuel de restauration hydromorphologique des cours d'eau – 3. Typologie des opérations de restauration et éléments techniques – Fiche 10 : Remise à ciel ouvert de cours d'eau, pp55-59, 2007 (in French)
- Agence Française pour la Biodiversité (ex. ONEMA) - La remise à ciel ouvert d'un cours d'eau http://www.onema.fr/recueil_restauration_hydromorphologie

V/ Author(s)

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Pyrène Larrey-Lassalle	Nobatek/INEF4	Writer
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Marjorie Musy	Cerema	Reviewer

> VEGETATION ENGINEERING SYSTEMS FOR RIVERBANKS EROSION CONTROL

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

Soil bioengineering and biotechnical slope protection is the use of plants and plant materials (brush) to control erosion along streambanks. Vegetation engineering techniques can recreate technically and biologically functional natural banks using living plants as strengthening materials.

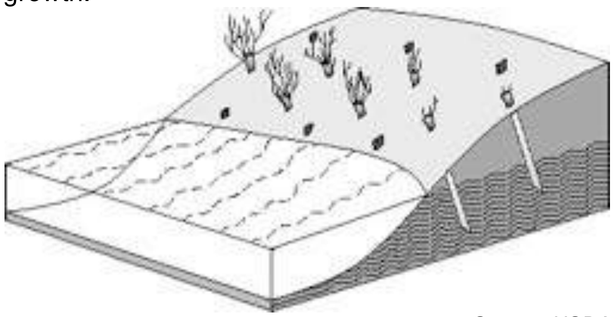
Various streambank stabilization methods exist[1], depending on the local conditions, typically the extent of the bank erosion problem, the stream velocity and depth, the bank slope and height, or the construction and maintenance budgets for the NBS implementation.

Seeding of streambank: Planting of grasses on a streambank to reinforce a bare streambank.

Streambank before and after seeding (Source: Iowa DNR)

Vegetation protects against runoff and erosion.

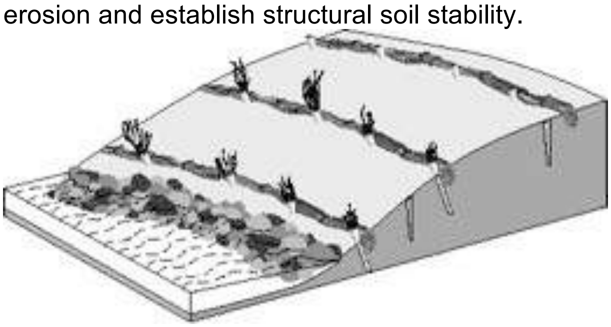
Live stakes: Placement of woody plant and tree cuttings on a graded bank to grow and stabilize the bank by the formation of roots and above ground growth.



Source: USDA

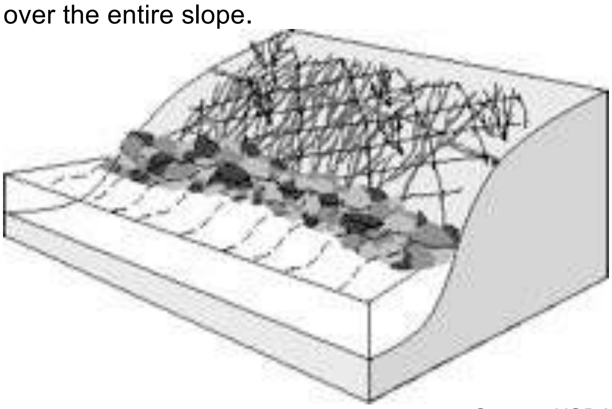
Note that live stakes can be combined with rocks (**joint planting**).

Live fascine (or wattle): Placement of bundles of living branches in trenches to slow over-bank erosion and establish structural soil stability.



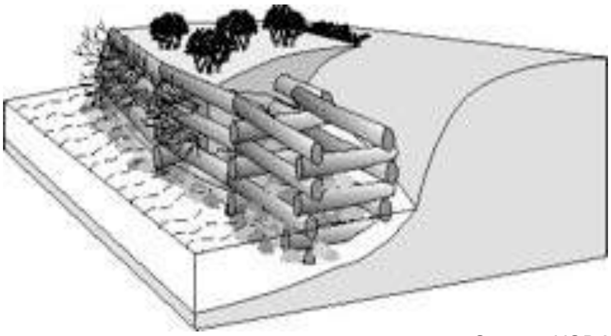
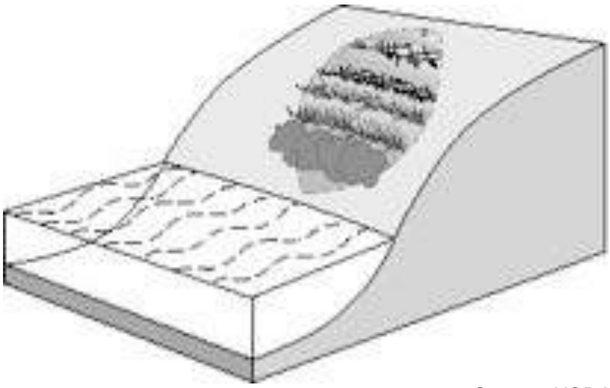
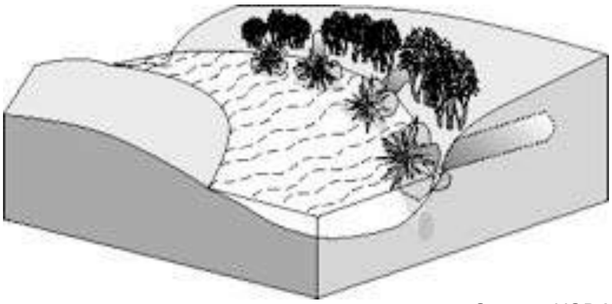
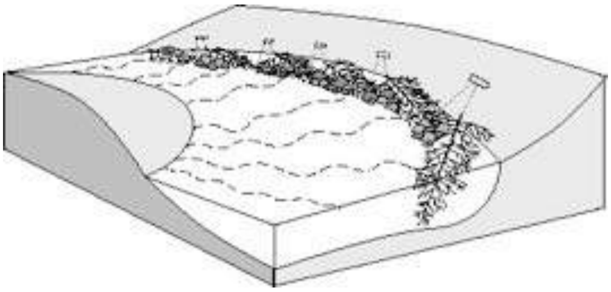
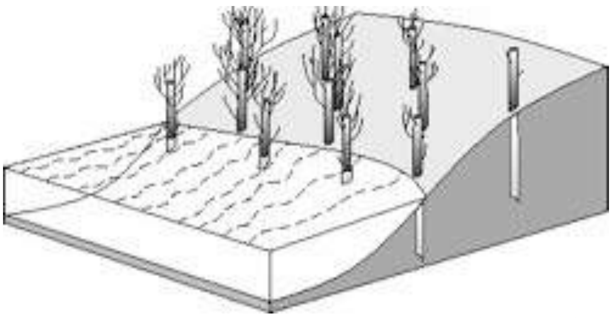
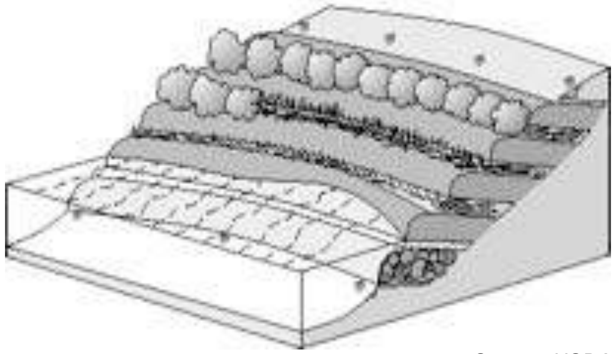
Source: USDA

Brush mattress: Combination of rip-rap, live fascine, live stakes, and brush to form a covering over the entire slope.



Source: USDA

[1]According to the definition of NBS considered in the Nature4Cities project, it was decided to exclude non-biological solutions from the scope of the study, and to only focus on living solutions.

Live crib wall: Hollow, box-like interlocking arrangements of untreated log or timber members filled above baseflow with alternate layers of soil material and live branch cuttings that root and gradually take over the structural functions of the wood members.  *Source: USDA*	**Branch-packing:** Layering of live branch cuttings and compacted soil to fill small holes and slumps of a streambank.  *Source: USDA*
Log, root wad, and boulder revetment: Logs are placed in the stream and held in place by boulders. The root masses are then placed around the boulders.  *Source: USDA*	**Tree revetment:** Placement of interconnected trees along the eroding streambank.  *Source: USDA*
Dormant post planting: Placement of medium-sized trees (e.g. cottonwood, willow, poplar) in the slope next to the stream (embedded vertically into streambank).  *Source: USDA*	**Vegetated geogrids:** Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile materials wrapped around each soil lift to rebuild and vegetate streambanks.  *Source: USDA*

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 04| Biodiversity and urban space > 04-1 Biodiversity	- Act as shock absorbers for heavy rainfall - Decrease water turbidity - Bind, retain and stabilize the soil to prevent and reduce streambank erosion and shallow sliding - Reduce flow velocities along eroding streambanks / Deflect flow from the bank - Provide aquatic organism shelter and improve habitat diversity - Provide a substrate for plant establishment - Encourage food web dynamics
Co-benefits and challenges foreseen	05| Soil management > 05-1 Soil management and quality	- Rebuild and vegetate eroded streambanks - Limit soil erosion
Possible negative effects	-	

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	From neighbourhood to agglomeration scales: streambank stabilization techniques are implemented at the local or watershed scale.
Impacted scales	A local project of streambank erosion control can affect the entire stream.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	For most of the techniques, the NBS is directly effective right after its implementation, but it can take more time for some stabilization methods, (in particular, when the growth of plants/trees is involved).
Life time	The life times of the streambank stabilization methods depend on the plant species used and on local conditions (in particular erosion forces such as water or wind). Living systems are designed to become part of the local landscape. For example, the live fascine is made of wood, which easily roots in contact with the earth (e.g. willow), so it eventually becomes a hedge.
Sustainability and life cycle	A priori, the NBS should generate less impact during the production, use and end-of-life phases than the traditional and conventional techniques currently used to address erosion problems (hard-armouring streambanks).
Management aspects (kind of interventions + intensity)	Each of the vegetation engineering techniques requires observation and maintenance of the streambank erosion control practices over time (about every 3 to 5 years). Observations should be made on a regular basis prior to and after major stream flow events. Maintenance activities should include the following: 1. Removal of any debris that becomes entangled in the erosion control material and could damage the bank materials. 2. Replacement of missing or damaged erosion control materials during times of low stream flow. 3. Application of fertilizer to plant materials to enhance their growth each year. 4. Application of fertilizer and weed control to buffer strip vegetation. 5. Restriction of livestock from steep banks and the areas containing the erosion control measures. Regular maintenance can be integrated as part of a multi-year maintenance program for the entire river.

II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	Landowner (private or public)
Technical stakeholders & networks	Although some simple stabilization techniques can be directly carried out by landowners, working in or near a stream poses special safety (particularly if the stream has steep or high banks or if the stream velocity is high), so using a qualified contractor who has the needed equipment and experience is recommended (Iowa DNR). The technical stakeholders' network for this kind of NBS is well identified.
Social aspects	No particular social bottleneck

II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	The best method for stabilizing and protecting the streambank from erosion depends on several factors, among which the size and location of the stream as well as the cause and severity of the erosion. Many installation advices are available for each streambank stabilization method (see for example Iowa or Georgia DNR guides in the USA). In any cases, the implemented NBS should: - Fit the system to the site (vegetation, hydrology, geology and soils, topography and exposure) - Limit removal of vegetation - Stockpile and protect top soil/materials - Protect exposed areas during construction
Materials involved	- Seed mixture - Live branch cuttings, live stakes (preferably native species of trees that root well and are locally available) - Logs and untreated timbers - Rock for riprap, backfill - Wire mesh, steel reinforcing bars, dead stout stakes - Geotextile fabric/erosion control fabric  *Newly stabilized bank with live stakes and erosion control materials* *© Cardno*  *Same bank after establishment* *© Cardno*

II.5 Legal aspects related

Local residents have rights relating to their property but also duties regarding the maintenance and development of rivers. Even when the river is State-owned, the maintenance of the banks and their protection can remain the responsibility of the riparian owner (it is the case in France, according to article L215 -14 of the Environmental Code). Prior to implement a streambank erosion control system, the property owner should obtain required permits and approvals for the construction or use of special materials.

II.6 Funding Economical aspects

Range of cost	Investment: - The price of seeding strongly depends on its composition: it varies between 1 to 3 € /m² (ENSEEIHT). - One cutting approximately costs between 1 and 3 € excluding VAT. A dense live stake implementation consists in planting 5 to 6 cuttings per square meter. So the costs associated with the implementation of live stakes ranges between 5 and 18 € excluding VAT (SMARL and SINBIO). - The implementation of live fascines ranges between 50 and 100 € excluding VAT per linear meter (SMARL and SINBIO; ENSEEIHT).
Origin of the funds (public, private, public-private, other)	Depending of the owner of the land (can be public or private).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Vegetation engineering techniques can be used alone or combined with one another (e.g. brush mattress). When vegetation is combined with low-cost building materials or engineered structures, numerous techniques can be created for streambank erosion control.
Combining techniques provides custom-made solutions and increases efficiency. For example, live fascine is most effective when combined with live staking and riprap.

Various layers of riparian slope "restoration"
Source: Offcite.org © Courtesy Waller Creek Conservancy

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Integrated approach: the entire stream should be considered as a system, and any project implemented to control streambank erosion should consider impacts to the total system, not just on a single site. - In many cases, the best approach is to use a combination of methods to better adapt to specific local conditions and constraints. - For a better diversification and success of the work, it is preferable to use different species of shrubby willows and shrubs.
Limiting factors	- Difficulties for landowners to be aware of available vegetation engineering techniques and how to implement them. - Costs compared to conventional methods of hard armouring.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Other structural practices with limited or minimally functional vegetation or no re-vegetation exist. • Coconut fibre rolls • Jetty system • Iowa vanes • Piling with wire or geotextile fencing • Rock rip rap The last ones are traditional and conventional methods of hard armouring streambanks to address erosion problems. These methods often degrade the quality of aquatic habitat and contribute to erosion in other areas (e.g., downstream).
Close NBS	• Re-profiling river banks • Revegetation of aquatic planting

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Georgia Department of Natural Resources: streambank and shoreline stabilization - Techniques to Control Erosion and Protect Property, 2011

Iowa Department of Natural Resources: How to control streambank erosion, 2006

IV.2 Sources used in this factsheet

ENSEEIHT: Les techniques du génie végétal utilisées | Bureau d'Etudes Industrielles "Energies renouvelables et Environnement", html : hmf.enseeiht.fr, accessed January 2018

Georgia Department of Natural Resources: streambank and shoreline stabilization - Techniques to Control Erosion and Protect Property, 2011

Iowa Department of Natural Resources: How to control streambank erosion, 2006

SMARL and SINBIO : Etude préalable pour une gestion raisonnée des étangs du bassin versant de la Largue - Fiche P : Solutions contre l'érosion des berges des cours d'eau à proximité des étangs, 2011

USDA: "Stream Corridor Restoration: Principles, Processes, and Practices, 10/98, Federal Interagency Stream Restoration Working Group (FISRWG).

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Pyrène Larrey-Lassalle	Nobatek/INEF4	Writer
Patrice Cannavo	Agrocampus Ouest	Reviewer
Ryad Bouzouidja	Agrocampus Ouest	Reviewer
Marjorie Musy	Cerema	Reviewer

- **Water**
  - **Natural and semi-natural water bodies and hydrographic network**
  - **Constructed wetlands and built structures for water management**

➢ Water

➢ Constructed wetlands and built structures for water management

> **SWALE**

> **DE-SEALED AREA**

> **CONSTRUCTED WETLAND FOR WASTEWATER TREATMENT**

> **FLOODPLAIN**

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Swales are broad, shallow, earthen channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Swales are often densely planted with a variety of trees, shrubs, and grasses along the bottom and sides of the channel.

Two primary vegetated swale design variations exist: dry swales and wet swales.

Dry swales:
Dry swales are designed with highly permeable soils and an underdrain to allow the entire stormwater volume to convey or infiltrate away from the surface of the swale shortly after storm events. Dry swales may be designed with check dams that act as flow spreaders and encourage sheet flow along the swale. Because of their highly permeable soil and conveyance capability, dry swales are more applicable for urban environments.

Dry swale
(Source: Sustainable storm water management)

Wet swales:
Wet swales are essentially linear wetland cells. Their design often incorporates shallow, permanent pools or marshy conditions that can sustain wetland vegetation, which in turn provides potentially high pollutant removal. A high water table or poorly drained soils are a prerequisite for wet swales. The drawback with wet swales, at least in residential or commercial settings, is that they may promote mosquito breeding in the shallow standing water. Infiltration is minimal.

Wet swale
(Source: Sustainable storm water management)

Grass swales:
Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than vegetated swales. However, they provide far less infiltration and pollutant removal opportunities. Design of grass swales is often rate-based, as opposed to volume-based.

Enhanced Vegetated Swales:
In addition to the required elements of a Vegetated Swale, the Enhanced Vegetated Swale includes an aggregate bed or trench, wrapped in a non-woven geotextile, which substantially increases volume control and water quality performance, although costs also are increased.

Vegetated swales along residential area (left) and along road (right)
(Source: Pennsylvania Stormwater Management Manual)

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	02| Water management > 02-1 Urban water management > 02-2 Flood management	- Removal of urban pollutants through infiltration and vegetative filtering - Reduction of runoff rates and volumes (by increasing flow path lengths and channel roughness) -Decrease of stormwater volume through infiltration
Co-benefits and challenges foreseen	04| Biodiversity and urban space > 04-1 Biodiversity 05| Soil management > 05-1 Soil management and quality	- Local wild grass and flower species can be introduced for visual interest and to provide a wildlife habitat - Swales catch pollutants, which are concentrated into a limited and dedicated zones
Possible negative effects	-	-

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The NBS is implemented at the neighbourhood scale. Published standards suggest that the optimal length of vegetated swales is between 30m and 60m (local scale).
Impacted scales	Neighbourhood scale.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	The NBS is directly effective right after its implementation.
Life time	The lifetime is generally large, around 50 years (The Bay Area Stormwater Management Agencies Association, 1997).
Sustainability and life cycle	A priori, no major impact associated with the life cycle of the NBS. The use phase is the phase most likely to generate impacts (for example, positive impacts regarding the services provided by the NBS).
Management aspects (kind of interventions + intensity)	Compared to other stormwater management measures, the required upkeep of vegetated swales is relatively low. In general, maintenance strategies for swales focus on sustaining both the hydraulic and pollutant removal efficiency of the channel, as well as maintaining a dense vegetative cover. Interventions occurring annually (semi-annually the first year) or 48 hours after every major storm event include: - Inspecting and correcting erosion problems, damage to vegetation, and sediment and debris accumulation - Inspecting vegetation on side slopes for erosion and formation of rills or gullies - Inspecting for pools of standing water; dewater and discharge to a sanitary sewer - Mowing and trimming vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation - Soil clogging by sediments and possible scraping - Inspecting for litter; to be removed prior to mowing - Inspecting for uniformity in cross-section and longitudinal slope - Inspecting swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage
II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	Landowner (private or public)
Technical stakeholders & networks	- Specialized green spaces management firms and gardeners: easy NBS to implement (mechanical digger) - The technical stakeholders network for this kind of NBS is well identified
Social aspects	No particular social bottleneck
II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	A major concern when designing vegetated swales is to make sure that excessive stormwater flows, slope, and other factors do not combine to produce erosive flows, which exceed vegetated swale capabilities. Use of check dams can enhance swale performance in such situations.
Materials involved	- If the infiltration capacity is compromised during construction, the first several feet shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. - Natural wood OR sand, gravel, and sandy loam or stones for check dams, gravel and pipes for underdrain system, if required - Seed and vegetate: dense and diverse selection of native, close-growing, water-resistant plants with high pollutant removal potential.

II.5 Legal aspects related

In France, rainwater management is regulated by several articles of the civil code.
In particular, some areas have to delimited:

- areas for which soil sealing must be limited,
- areas for which collection, storage or even treatment are necessary,
- flood risk areas (in order to implement flood prevention practices).

II.6 Funding Economical aspects

Range of cost	The cost of installing and maintaining swales varies widely with design variability, local labour / material rates, real estate value, and contingencies. In general, swales are considered relatively low cost control measures. The Bay Area Stormwater Management Agencies Association (1997) gives construction costs (per linear foot) from \$4.50 to \$8.50 (from seed) or from \$15 to \$20 (from sod), annual operations and maintenance costs (per linear foot) of \$0.75, and a total annual cost (per linear foot) from \$1 (from seed) to \$2 (from sod). Costs, which include activities such as clearing, grubbing, levelling, filling, and sodding (if required), may range from \$8.50 to \$50.00 per linear foot depending on swale depth and bottom width (South-eastern Wisconsin Regional Planning Commission, 1991).
Origin of the funds (public, private, public-private, other)	Depending of the owner of the land (can be public or private).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Check dams and berms can be installed across the flow path of a swale in order to promote settling and infiltration. Check dams are recommended for vegetated swales with longitudinal slopes greater than 3%. Check-dams create a series of small, temporary pools along the length of the swale, which make it much more effective at mitigating runoff. The frequency and design of check-dams in a swale will depend on the swale length and slope, as well as the desired amount of storage/treatment volume.

Check dams along a vegetated swale
(Source: Pennsylvania Stormwater Management Manual)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- The effectiveness of a vegetated swale is directly related to the contributing land use, the size of the drainage area, the soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. - Swales are most efficient when their cross-sections are parabolic or trapezoidal in nature. Swale side slopes are best within a range of 3:1 to 4:1 and shall never be greater than 2:1 for ease of maintenance and side inflow from sheet flow. - Swales are easy to incorporate into landscaping - Low capital cost - Maintenance can be incorporated into general landscape management - Pollution and blockages are visible and easily dealt with.
Limiting factors	- The soil base for a vegetated swale must provide stability and adequate support for proposed vegetation. When the existing site soil is deemed unsuitable (clayey, rocky, coarse sands, etc.) to support dense vegetation, replacing with approximately 30 cm of loamy or sandy soils is recommended. Swale soils shall also be well drained. - Swales are not suitable for steep areas or areas with roadside parking - Limited opportunities to use trees for landscaping - Risks of blockages in connecting pipe work
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Vegetated swales provide a cost-effective and an environmentally superior alternative to conventional curb and gutter conveyance systems, including associated underground storm sewers.
Close NBS	• Rain/infiltration gardens • De-sealed areas and associated systems • Constructed wetland for phytoremediation • Constructed wetland for wastewater treatment • Use of terraces

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Coulon, A., El-Mufleh, A., Cannavo, P., Vidal-Beaudet, L., Béchet, B., Charpentier, S. (2013) Specific stability of organic matter in a stormwater infiltration basin. Journal of Soil and Sediments 13, 508-518

Coulon, A., Cannavo, P., Charpentier, S., Vidal-Beaudet, L. (2014) Clogging process of stormwater infiltration basins quantified by image analysis. Journal of Soil & Sediments, DOI 10.1007/s11368-014-0951-z (IF 2013 : 2.107, Quartile Q2 en sciences du sol)

. (IF: 2.107, Quartile Q2 en sciences du sol)

IV.2 Sources used in this factsheet

Pennsylvania Stormwater Management Manual, Section 5 - Structural BMPs

V/ Author(s)

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Ryad Bouzouidja	Agrocampus Ouest	Reviewer
Marjorie Musy	Cerema	Reviewer

> DE-SEALED AREA (and associated systems, e.g. permeable paving)

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	"De-sealing" consists in replacing impervious surfaces with more permeable surfaces, in order to recover major soil functions: water infiltration capacity, soil-atmosphere exchange, carbon storage, biodiversity, etc.

Urban spaces are often sealed while alternative solutions exist. When possible, keeping an open ground is the least impactful solution for the water cycle and for the environment. Where pavement is necessary, the use of pervious materials can be an alternative to conventional asphalt mixes. Vegetated or semi-vegetated solutions can, in addition, promote biodiversity.

More generally, many "permeabilising" techniques, which favour the rainwater infiltration and/or retention, exist and provide an alternative to the traditional network of pipes for water management, e.g. swales, infiltration wells, reservoir structures, basins, roofs ponds, green roofs, rain gardens… As these techniques are already detailed in other NBS sheets, we propose to focus here on **pervious (permeable or porous) pavements and drainage trenches.**

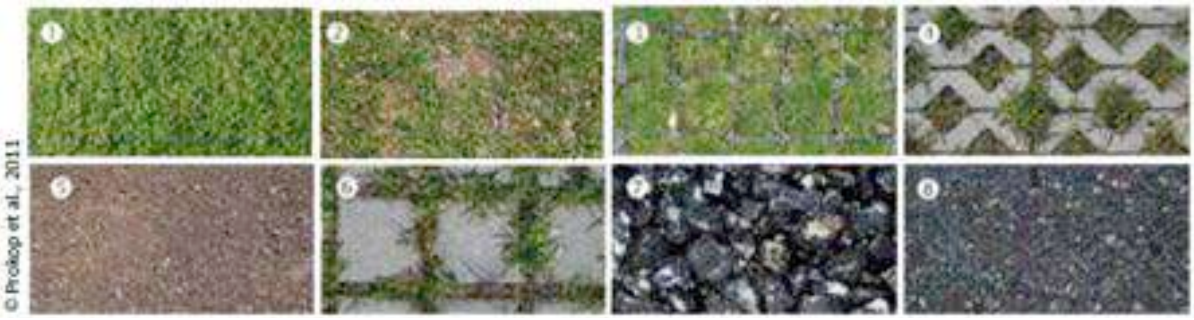
Pervious pavements:
Two main types of pervious pavements exist: (1) permeable pavements (e.g. interlocking concrete pavers) are made of impermeable modular elements, but voids between elements allow water infiltration and soil-atmosphere gas exchange and (2) porous pavements (e.g. porous concrete), instead, are made of even-graded inert bound by a permeable binder (e.g. epoxy resin), and are permeable along their entire surface (Fini et al., 2017).

Example of grass slab
(Source: Cerema)

Drainage trenches:
Trenches are superficial and linear structures filled with porous materials and capable of temporarily storing rainwater. Trenches collect runoff, clog volumes and flows, and drain rainwater.

Drainage trench
(Source: Cerema)

Examples of pervious pavements (1-7):



Pervious materials ((1) lawn, (2) gravel-lawn, (3) plastic lawn slabs, (4) concrete lawn slabs, (5) porous concrete pavements, (6) stone-paved surfaces, (7) porous asphalt) vs. impervious pavement ((8) impervious asphalt)

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate Issues > 01-1 Climate adaptation 02| Water Management > 02-1 Urban water management and quality > 02-2 Flood management 05| Soil management > 05-1 Soil management and quality	- Reduction of urban heat-island effect (less heat storage, more evapotranspiration) - Decrease of rainwater volumes in unitary networks (less water treatment) - Reduction of overflows (prevention of flooding and mudslides) - Reduction of runoff and leaching of pollutants through infiltration - Groundwater recharge - Preservation of soil functions (support for food production, water filtration, removal of contaminants, etc.)
Co-benefits and challenges foreseen	04| Green Space and Biodiversity > 04-1 Biodiversity 06| Resource efficiency > 06-4 Recycling	- Increase of biodiversity (functional habitats for fauna and flora, less habitat fragmentation)- - the possibility to recycle stones/pavement
Possible negative effects	05| Soil management > 05-1 Soil management and quality	- increase the biological activity and reduce the Stock in Organic matter

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales

Scale at which the NBS is implemented	The NBS is mainly implemented at the local / neighbourhood scale.
Impacted scales	Can affect the water cycle from the local to the agglomeration scale.

II.2 Temporal perspective (including management issues)

Expected time for the NBS to become fully effective after its implementation	The NBS is directly effective right after its implementation.
Life time	The life time strongly depends of the implemented NBS. For example, porous concrete can easily reach a lifetime of several decades (conseils-experts.batiproduits.com).
Sustainability and life cycle	Vegetated or semi-vegetated solutions (unlike continuous, full surfaces) require less material extraction (e.g. asphalt, concrete).
Management aspects (kind of interventions + intensity)	Vegetated or semi-vegetated solutions may require more maintenance. For example, lawn slabs will need specific maintenance, expensive daily cleaning (manual) and weeding.

II.3 Stakeholders involved / social aspects	
Stakeholders involved in the decision process	This kind of NBS is intended to be implemented by any public or private project owner who has impervious surfaces (roads, car parks, activity and residential areas, public or private spaces e.g. squares, terraces, etc.). In France, this is particularly relevant for local authorities in charge of schemes for territorial coherence or local urban plans (and water development and management plans, who can implement territorial projects that take into account the problems raised by surface sealing.
Technical stakeholders & networks	Specialized companies provide these alternative products. The technical stakeholders' network for this kind of NBS is well identified.
Social aspects	Can be seen as less robust than conventional, sealed surfaces. Positive aspects: greener living environment, participatory process / residents' involvement (e.g., in Strasbourg, some de-sealed areas are vegetated and managed by the inhabitants via a convention).
II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	Public or private land planning actors must take into account this issue in their development planning process: each urban renewal operation (and in particular those of large scale) must be an opportunity to ask the question of "de-sealing" or "permeabilising" certain types of areas (such as roads and their surroundings, car parks, buildings surroundings, squares, paths, tree bases, etc.)
Materials involved	Gravel, plastic slabs, concrete slabs, permeable concrete pavements, porous asphalt…

II.5 Legal aspects related

In France, numerous laws and regulations contribute to the limitation of soil sealing or its effects (Poudevigne et al. , 2017).

It mainly concerns project owners, but also public entities that set development rules:
- at the scale of the territory (SCoT, PLU, SAGE, zonings and regulations related to water sanitation)
- at the scale of urban planning/development (mixed development zone referred to as ZAC, project owner)
- at the community level, under the other prerogatives of the local authorities

II.6 Funding Economical aspects

Range of cost

The range of cost strongly depends of the implemented NBS, and of its scale of implementation (local / whole project of urban development).

Examples:
- At the material scale:

Draining concrete pavements (www.prix-pose.com/beton-drainant): The cost of draining concrete slabs usually ranges from 20 €/m² to 25 €/m², although industrial draining concrete (high performance) can cost up to 35 €/m². Draining concrete in bulk is cheaper (between 15 €/m² and 25 €/m² with cement and granulate).

Concrete lawn slabs (www.pierreetsol.com): Price around 20 - 25 €/m^2

- At a project scale:

De-sealing the riverbanks of the Rhone in the city of Laveyron (France) consisted in replacing a basketball court and an asphalt car park by a permeable amphitheatre of greenery and by a grassed car park, and in implementing swales and an esplanade for rainwater recovering. It cost € 242,000 for a total de-sealed area of 900 m^2 (Poudevigne et al., 2017).

Origin of the funds (public, private, public-private, other)

Depending of the project owner (can be public or private).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

"De-sealed areas" already includes a broad range of NBS types, which can be combined.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	For the example of lawn slabs: - Simple design - Good integration into the urban environment - Suitable for pedestrian footpaths, car parks, light traffic loading, bike paths, driveways and earthworks More generally, these types of NBS can be implemented in various locations in the city (e.g., central reserves, squares, sidewalks, car parks...)  *Central reserves in Strasbourg* *© EuroMétropole de Strasbourg*
Limiting factors	For the example of lawn slabs: - Too many plants close to the NBS (risk of clogging, which can be reduced with alveolar/hollow slabs) - Specific maintenance In addition, and more generally for these types of NBS, infiltration will not be optimal in all sites because of soil, health or environmental factors (Poudevigne et al., 2017), such as: - Soils containing clay (impermeable): not favourable to infiltration - Soils containing gypsum (soluble): risk of ground destabilization - Presence of karstic formation: risk of pollution of the aquifer in the absence of soil for trapping pollutants - Proximity of the groundwater table: risk of flooding, risk of groundwater pollution - Steep slope - Presence of old quarries: risk of ground destabilization - Presence of polluted sites: risk of pollutants spreading - Presence of areas for the abstraction of drinking water: risk of pollution - Insufficient surface area: risk of ineffective infiltration (surface ratio)

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Conventional pavement (asphalt and concrete materials) and traditional network of pipes for water management
Close NBS	• Unsealed car parks • Swales • Rain/infiltration gardens • Use of terraces

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Fini, A., Frangi, P., Mori, J., Donzelli, D., Ferrini, F., 2017. Nature based solutions to mitigate soil sealing in urban areas: Results from a 4-year study comparing permeable, porous, and impermeable pavements. Environ. Res. 156, 443–454. https://doi.org/10.1016/j.envres.2017.03.032

Poudevigne, M., Billon, V., Charrier, G., Pojer, K., 2017. Guide technique du SDAGE : Vers la ville perméable - Comment désimpérméabiliser le sols ?

IV.2 Sources used in this factsheet

Poudevigne, M., Billon, V., Charrier, G., Pojer, K., 2017. Guide technique du SDAGE : Vers la ville perméable - Comment désimpérméabiliser le sols ? (in FRENCH)

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> CONSTRUCTED WETLAND FOR WASTEWATER TREATMENT

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS essentially consists of the implementation of constructed wetlands (CWs). CWs are engineered wetlands that have been designed and constructed to make the most of natural processes for treating wastewater, but do so in a more controlled environment than natural wetlands. In urban environments, this NBS will provide a sustainable source of irrigation water, a new model of green/blue infrastructure or urban park at low cost and a support in the water management strategy of the city.

Different variants existing

CWs can be categorized taking into account different criteria, but the most common classifying parameter is their hydrology. According to this, CWs can be classified into three main variants:

=> Free water surface CWs (FWS-CWs)

They are open water areas that contain floating, submerged, and emergent plants. Fig. 1 schematically explains how they run. In summary, as wastewater flows through the wetland, it undergoes different physical, chemical, and biological processes that remove the pollution that it contains. Namely, sedimentation, filtration, and microbiological degradation are the key removing processes in FWS-CWs. They provide efficient removal of suspended solids, organics, and ammonia; nitrogen removal efficiency is usually high too, whereas phosphorus removal efficiency is low. They are used in the tertiary treatment of municipal wastewaters and stormwater runoffs. One example of urban integrated FWS-CWs is shown in Fig. 2.

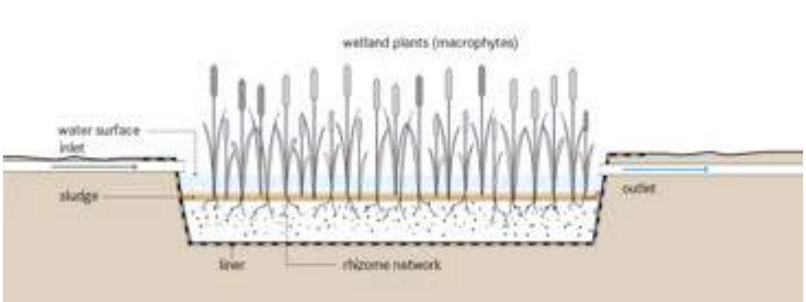

Figure 1 (© SSWM University)

Figure 2 (© domusweb)

=> Horizontal subsurface-flow CWs (HF-CWs)

In this case, the wastewater is fed at the inlet and slowly flows horizontally through a porous media in which emergent vegetation is planted, Fig. 3. This water is consequently filtered and, furthermore, it undergoes some aerobic, anoxic, and anaerobic processes that purify it. HF-CWs are more robust systems than FWS-CWs and also remove suspended solids and organics efficiently; however, their ability to remove nitrogen depends on several factors, and their ammonia and phosphorus removal efficiencies are low. Among others, they are used in secondary treatments of municipal wastewaters One example of urban integrated HF-CWs is shown in Fig. 4.

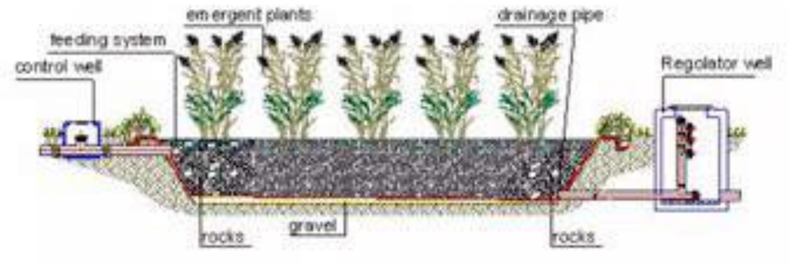

Figure 3 (©cgi.tu-harburg)

Figure 4 (©nawatech)

=> Vertical subsurface-flow CWs (VF-CWs)

It differs from the previous variant in the direction that wastewater follows through the porous media, Fig.5. Now, large batches of water are fed on the surface, thus flooding it. Wastewater must then percolate down through the bed to leave the system. VF-CWs provide greater O_2 transfer into the bed than HF-CWs, thus producing NO_3^- rich effluents which cannot be obtained by HF-CWs processes. Their technical complexity makes them fit small treatment areas better, so that they are suitable for treating one-site domestic or small communities wastewaters. One example of VF-CWs is shown in Fig. 6.
On the other hand, VF-CWs and HF-CWs are combined in the so-called hybrid systems, which improve their individual performances, above all when regarding nitrogen removal.

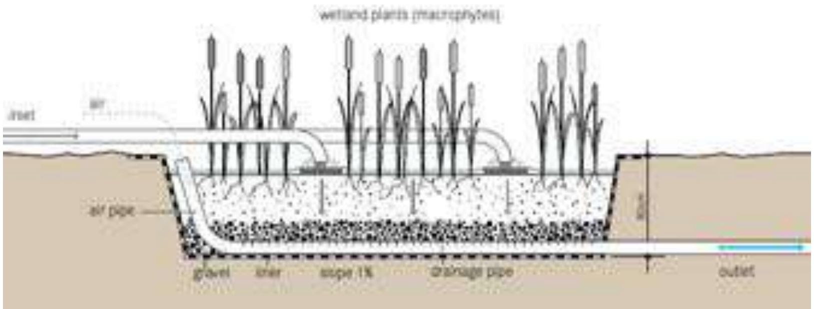

Figure 5 (©ecompendium.sswm)

Figure 6 (©nawatech)

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02I Water management >02-1 Urban water management 04I Green space management and biodiversity >04-1 Biodiversity >04-3 Urban space development and regeneration	-A sustainable source of irrigation water - Use of new vegetated surface waterbodies in urban areas as a natural processes for treating wastewater - Low cost and sustainable wastewater treatment - Creation of new vegetated surface waterbodies - Reduce costs related to loads into sewerage systems - Reduce pollutants contained in waters - Increase biodiversity - Increase of quality and quantity of green and blue existing, restored and new NBS
Co-benefits and challenges foreseen	01I Climate >01-2 Climate adaptation 02I Water management >02-2 Flood management 07I Public health and well-being >07-2 Quality of life 09I Urban planning and governance >09-1 Urban planning and form	- Constitute fresh areas - Reduce run-off - Flood peak reductions - Changing images of the urban environment - Increase citizen participation in the management of NBS, above all in the case of small-sized CWs, which can be managed by the neighbours who have the CW in their own property. - Increase amount of green open space for residents
Possible negative effects	04I Green space management and biodiversity >04-4 Acoustics 06I Resource efficiency >06-3 Waste 07I Public health and wellbeing >07-2 Health	- Presence of noisy species, mainly aquatic birds - Management of soils and death plants which can contain hazardous pollutants - Presence of undesired insects - Increase of ambient humidity (depending on the location)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Neighbourhood and city. It must be remarked that city-scaled CWs can only be implemented in growing cities, where there is still enough free space for these NBS to be installed. This scale is not applicable to highly populated cities since there, it is almost impossible to get all the required land.
Impacted scales	The scales at which the NBS can be implemented depend on the chosen CW hydrology. FWS-CWs and HF-VWs can be implemented at a city-sized scale, but this alternative is limited by the requirement of free lands. VF-CWs better fits a neighbourhood-sized scale, what makes the implementation of this technology in an urban context easier.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	It is directly related to the growth of the plants, no other aspect should delay their set-up. Floating and submerged plants grow fast so that their growth should not be time limiting. The growth of emergent plants may be the most long-lasting but this time should not exceed a few weeks or even a month. If seasonal plants are used, it must be considered that some of the purifying processes associated to those plants will not occur throughout the whole year.
Life time	Long-term effective treatment performance in CWs remains a challenge. The operational problems that the running of HF-VWs and VF-VWs involve limit their lifetime to 10 years. FWS-CWs lifetime can be extended up to several decades.
Sustainability and life cycle	CWs offer a more environmentally sustainable alternative to treat wastewaters than traditional treatments. Once exhausted, the dismantlement of the wetland is not

	technically difficult; furthermore, this activity will be easier because of the small size of the CWs in urban locations. The management of the removed plants and soils is the main concern about the sustainability of these systems, since these materials can contain certain compounds that may turn them into polluting residues. However, this risk is not applicable in most cases. In the same way, the death of the plants during the lifetime (due to natural or external causes like freezing) of the CW must be well controlled since the pollutants they contain the pollutants they contain are released into the water again,, thus resulting in poor removal performances.
Management aspects (kind of interventions + intensity)	The management activities also depend on the hydrology of the CW. • FWS-CWs only need punctual activities to run properly. They are able to dampen heavy rains and stormwater runoffs, but their plants can be harmed by frosts or peaks of pollutants in the wastewaters. In case the plants die because of these external phenomena, they must be replaced. • Apart from the need of control during/after harmful phenomena, HF-CWs and VF-CWs need further interventions because they are quite sensitive to clogging. This problem should be avoided as much as possible thanks to an efficient design, but a continuous management of the CWs is needed to assure a correct flow of the wastewaters.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	For city-sized scale CWs, local authorities or even regional authorities, depending on the location. For neighbourhood-sized scale CWs, local authorities or, if the CW is going to treat or process the wastewaters from a small community and it is settled inside their private zones, the own community.
Technical stakeholders & networks	Engineering and agricultural tasks are needed, so the implementation can be made by firms which provide both services or networks of enterprises with more specific profiles. Once the implementation has been completed, the periodic control of the facilities does not need a so highly qualified staff. Some kinds of CWs may even be managed by the own citizens.
Social aspects	• When appropriate, it is necessary to reach an agreement with all the co-owner of a community. • Necessity to inform the neighbours that the possible drawbacks (humidity, smells, insects, noises) are well balanced by an environmentally friendly and economical efficient technology.
II.4 Design / techniques/ strategy	
Knowledge and know-how involved	The design of CWs needs for specific know-how and, if possible, a wide background in the field. Two kinds of factors must be considered during this process. First, several ambient factors, from the location and the local weather, to the pollutants the CW will have to deal with, among others. Second, design parameters like plants and substrate selections, and the optimization of the CW configuration. When the basic morphology is modified or CWs are combined with other technologies, as described later in section II.7., the designing process turns even more complex.
Materials involved	For classic CWs the following materials are needed: • Building materials for the structure and the liner: cement, gravel, piping, etc. • Plants: more than 150 macrophyte species, like Phragmites spp. Typha spp, or Scirpus spp., have been used in CWs globally. • Soil: they range from natural materials (sand, gravel), to artificial products (activated carbon, compost) or even industrial by-products (ashes, oil palm shell). Specific materials are required for any modification or combination of those classic

	configurations with other technologies. E.g., the implementation of an electrowetland needs for the building of a complete electrical circuit. That implies electrodes, electron collector layers, an external circuit, and an energy harvesting and energy system.

II.5 Legal aspects related

The installation of wetlands in public zones needs to meet the municipal/regional normative; when the CW is going to be settled in a private zone, the agreement of all of the owners of this zone is mandatory.

II.6 Funding Economical aspects

Range of cost	Low-costing is one of the main advantages of CWs in comparison to other alternatives. Any wastewater treatment technology will always be much more expensive than CWs to operate. CWs building costs can be broken down into the following components: excavation, liner, plants, gravel, distribution and control structures, and fencing. In its report about processes, performance, design and operation of CWs (Kadlec et al., 2000), the IWA Specialist Group in Use of Macrophytes in Water Pollution Control reported a thorough analysis of CW economics. They collected data about the building capital costs of several tens CWs and reached the following conclusions. The average building cost of FWS-CWs was 58.000 $\$\cdot ha^{-1}$ (please note that the prize is expressed in US dollars of year 2000), although this value ranged from 10.000 to 150.000 $\$\cdot ha^{-1}$. The average building cost of subsurface flow-CWs was 388.000 $\$\cdot ha^{-1}$, although this value ranged from 80.000 to 2.000.000 $\$\cdot ha^{-1}$. The operating and maintenance costs of CWs include pumping energy, compliance monitoring, dike maintenance, and equipment replacement and repairs. The sum of these activities is relatively inexpensive. Annual costs can be estimated to range from 2.500 to 5.000 $\$\cdot ha^{-1}\cdot year^{-1}$.
Origin of the funds (public, private, public-private, other)	The origin of the wastewaters treated by a CW establishes the origin of the funds. If a CW treats waters from a neighbourhood or even a whole city it must be funded by public institutions. If a CW is implemented for private purposes, the community or private users must cover its funding.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

The three configurations described in section I.1. are the most basic variants. They have been used for several decades, but new insights and advances keep appearing in this field that focus on promoting the purifying ability of FWS-CWs, HF-CWs, and VF-CWs. Providing a suitable thermal conditioning, recirculating the effluents, supplying external carbon sources, or harvesting biomass are some of them. Other modifications of classic CWs have been also carried out within this chase for higher efficiencies. E.g., they have been combined with other technologies (artificial aerated CWs, electrowetlands (Fig. 7)), adapted to novel configurations (towery hybrid CWs, circular flow corridor CWs, baffled subsurface flow CW) or combined with other wastewater treatment systems (microbial fuel cell CW, biological reactor-combined CW (Fig.8)).
All of these strategies have achieved to improve the efficiency and widen the availability of these systems.

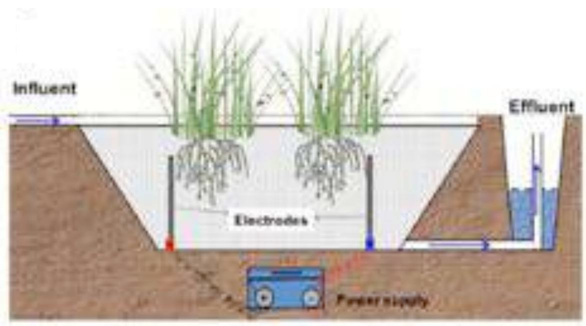

Figure 7 (Ju et al. 2014)

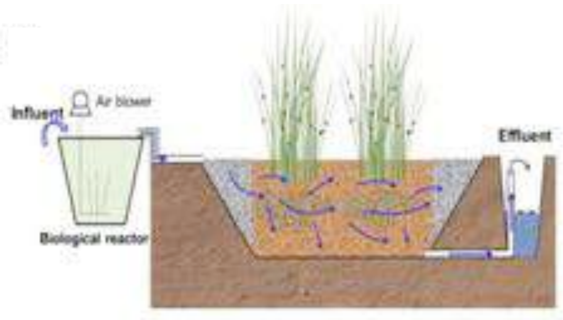

Figure 8 (Bilgin et al. 2014)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	All of the following parameters must be optimized to achieve an efficient CW: • Plant selection: constitution of the plants, tolerance to waterlogged-anoxic and hyper-eutrophic conditions, capacity of pollutant absorption, adaptation to extreme climates. • Substrate selection: it must provide a suitable growing medium for the plants, allow a successful movement of wastewaters, and efficiently absorb the widest variety of pollutants. • Optimization of design and operation: besides the election of the hydrology, other parameters like water depth, hydraulic load and retention time, or feeding mode are critical.
Limiting factors	Land requirements for CWs is the most limiting factor for their broad application, especially in those regions where land resources are scarce and population density is high. The design of the CWs, their management (namely for HF-CWs and VF-CWs), and the ability of these facilities to overcome extreme weather and polluting situations are the other factors limiting the efficiency of this NBS. From a social point of view, it must be considered that the settlement of CWs, FWS-CWs above all, noticeably changes the look of urban locations. Then, if a wide acceptance is chased, the advances provided by this technology must be properly introduced to the involved population.

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Activated sludge process is the most common technology within wastewater treatment field. Concurrently to the development of CWs systems, other technologies have arisen during the last decades whose aim is improving the performance offered by activated sludge. Some of them like ozonation or chlorination focus on degradation while others like biological activated carbons or membrane bioreactors offer more complete treatments. Regarding the previous solutions, CWs are undoubtedly the most sustainable and one of the most cost-effective technologies applied for wastewater treatments. Furthermore, if they are designed suitably, they are efficient enough to compete with the rest of alternatives.
Close NBS	• Swales: not treatment of wastewaters • Rain/infiltration gardens: focused on rainwater run off • De-sealed areas (and associated systems) • Use of terraces (based on cultivation terraces principles) None of them focuses on purifying polluted waters. CWs for phytoremediation do, but full-scale applications are still limited for this technology.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

BILGIN, Melayib, SIMSEK, Ismail, TULUN, Sevket, 2014, *Treatment of domestic wastewater using a lab-scale activated sludge/vertical flow subsurface constructed wetlands by using Cyperus alternifolius*, Ecological Engineering, Vol. 70, pages 362-365.

DIEMONT, Stewart A.W., 2006, *Mosquito larvae density and pollutant removal in tropical wetland treatment systems in Honduras*, Environmental International, Vol. 32, pages 332-341.

JU, Xinxin, WU, Shubiao, ZHANG, Yansheng, DONG, Renjie, 2014, *Intensified nitrogen and phosphorus removal in a novel electrolysis-integrated tidal flow constructed wetland system*, Water Research, Vol. 59, pages 37-45

KADLEC Robert H., KNIGHT, Robert L., VYMAZAL, Jan, BRIX, Hans, COOPER, Paul, HABERL, Raimund (IWA Specialist Group in Use of Macrophytes in Water Pollution Control), 2000, *Constructed wetlands for pollution control. Processes, performance, design and operation*, IWA Publishing, 171 pages.

KADLEC Robert H. and WALLACE Scott D., 2009, *Treatment wetlands*, Taylor & Francis Group, 366 pages.

PRASSE, Carsten, STALTER, Daniel, SCHULTE-OEHLMANN, Ulrike, OEHLMANN, Jörg, TERNES,Thomas A., 2015, *Spoilt for choice: A critical review on the chemical and biological assessment of current wastewater treatment technologies*, Water Research, Vol. 87, pages 237-270.

THORSLUND, Josefin, et al., 2017, *Wetlands as large-scale solutions: Status and challenges for research, engineering and management*. Ecological Engineering, Vol. 108, pages 489-497.

VYMAZAL, Jan, 2011, *Constructed wetlands for wastewater treatment: Five decades of experience*, Environmental Science and Technology, Vol. 45, pages 61-69.

WANG, Mo, ZHANG, Dong Qing, DONG, Jian Wen, TAN, Soon Keat, 2017, *Constructed wetlands for wastewater treatment in cold climate- A review*, Journal of Environmental Science, Vol. 57, pages 293-311.

WU, Haiming, FAN, Jinlin, ZHANG, Jian, NGO, Huu Hao, GUO, Wenshan, LIANG, Shuang, HU, Zhen, LIU, Hai, 2015, *Strategies and techniques to enhance constructed wetland performance for sustainable wastewater treatment*, Environmental Science Pollution Research, Vol. 22, pages 14637-14650.

WU,Haiming, ZHANG, Jian, NGO,Huu Hao, GUO, Wensham, HU, Zhen, LIANG, Shuang, FAN, Jinlin, LIU, Hai, 2015, *A review on the ustainability of constructed wetlands for wastewater treatment: Desgina and operation*, Bioresource Technology, Vol. 175, pages 594-601.

ZHANG, Baiyu, ZHENG, J.S., SHARP, Glenn R., 2010, *Phytoremediation in engineered wetlands: Mechanisms and applications*, 2010, Procedia Environmental Sciences, Vol. 2, pages 1315-1325.

IV.2 Sources used in this factsheet

https://sswm.info/

https://www.domusweb.it/

https://cgi.tu-harburg.de/

https://nawatech.net/

http://ecompendium.sswm.info/

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	For a long time, floodplains have been underutilized and ignored by urban planning with the only exception to serve as a reserve for water in the case of flood. With this NBS, urban planning can multiply the effective utilization of urban green spaces as they can become recreational areas with low intervention requirements, but with unique natural values, which can be a fundamental element of the ecological network along the river. This is an ancient solution which is now rediscovered.

Different variants existing

Two kinds can be identified, depending on the location and potential use of the area:

=> Urban recreational area in the city

This type gives everyday recreational possibility for the nearby living residents

The Hajógyári sziget at Budapest under water
(Source: https://www.facebook.com/hajogyari/)

The Sziget Festival at Hajógyári sziget
(Source: https://cosmopolitan.hu/)

Playground at Hajógyári sziget
(Source: www.picurgo.hu)

=> Waterfront recreational area near the city

This type can be used for weekend excursion or holiday

Walk “Tisza mayflower nature trail” at the floodplain of Tisza river near Szolnok, Hungary
(Source: www.kirandulastervezo.hu)

Fishing at the floodplain of Danube near to Budapest, Hungary
(Source: http://youtube.com)

Sugovica (backwater of Danube) Strand at Baja, Hungary
(Source: http://www.karpatinfo.net)

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 04| Green Space Management and Biodiversity > 04-1 Biodiversity 07| Public Health and well-being > 07-2 Quality of life 10| People security > 10-2 Extraordinary events	- Limit stormwater run-off, favour evaporation - Moderating the flood risks; - Providing a habitat for small mammals, birds and insects - Aesthetic value, offering space for recreation, contact with nature - Preventing other areas from flooding
Co-benefits and challenges foreseen	01| Climate issues > 01-1 Climate adaptation 03| Air quality > 03-2 Air quality locally 04| Green Space Management and Biodiversity > 04-1 Urban space development and regeneration 5 | Soil management > 5.1 | Soil management and quality	- Contributing to mitigate urban heat island - Helping filter air pollutants - Proposing a variety or green spaces, educational purposes -Improving soil biodiversity
Possible negative effects	07| Public Health and well-being 11| Green economy > 11-3 Direct economic value of NBS	Prohibited constructions & weekend houses can be legalized Undesired insects can proliferate after floods Huge amount of litter can appear after every significant flood.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Neighbourhood, city
Impacted scales	The scales impacted are mostly at least neighbourhood wide, but very often it can be interpreted on a city, or even regional scale.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1-2 years => linked to the growth of plants It could be longer considering the growth of trees, 10-15 years
Life time	It depends on the plant species: - More than 50-100 years for whole biotope
Sustainability and life cycle	Because this is a type of semi-natural area, where the plants are living and growing in their natural environment, the parks are sustainable for more decades.
Management aspects (kind of interventions + intensity)	The required interventions are: regular (monthly, or yearly, depending from the type of use) and after flood cleaning of the open places; the maintenance works for the constructed parts of the natural parks (e.g. playground tools, buildings, etc.)

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property), mostly the state, or local municipality
Technical stakeholders & networks	- Municipality - Landscape architects - Specialized green spaces management firms and gardeners.
Social aspects	- Importance of the participatory process. - Necessity to inform the public about the actual impact, to dispel any prejudice or resentment - Green solutions are usually popular and well-received

II.4 Design / techniques/ strategy

Knowledge and know-how involved	- Selection of plants adapted to the local specifics: • wet surroundings, high water level, • the local climate • step-proof grass, mass events, etc. • the traffic intensity - Choose the most suitable support system the landscape planning solutions (plants, woods, pavements, etc.) - Set up the appropriate plant maintenance framework
Materials involved	- Floodplain species of plants and trees - waterproof materials used for the constructed elements (playground tools, smaller houses, etc.

Floodplain vegetation with wooden bridge Tiszaliget Hungary *(Source: http://www.erdeszetierdeiiskolak.hu)*

Waterproof materials under water (wood, concrete, metal) at Római part, Budapest, Hungary *(Source: http://indafoto.hu)*

Playtools in the park joining to the floodplain (wood, metal, plastic) *(Source: www.picurgo.hu)*

II.5 Legal aspects related

To install public space, obtaining the authorization of the owners, and the competent authorities too.

II.6 Funding Economical aspects

Range of cost	Floodplain forest: 800-1500 € / ha without constructions Floodplain park: 35-50 € / m2 Maintenance: 10 person day / year
Origin of the funds (public, private, public-private, other)	- Municipalities' of state authorities' budget (flood control belongs to the state administration together with the floodplains, the local municipality is responsible for the parks in most cases).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with parks Linking the continuous green area with parks can produce a complex recreational area at the riversides and lakeshores - Combination of bio-materials Combination of green floodplain with a public park  Hajógyári sziget Budapest Hungary *(Source: www.nol.hu)*

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Location of the site - Good arrangement and adequate design - The proper additional establishments There is a strict regulation for what kind of human intervention in a floodplain can take place, its natural features are the most favourable. The ecosystem services of this kind of area can be widespread, from recreation to environmental education. Festivals and events with huge audience can take place.
Limiting factors	- A fear to greater damages of flood - Governance and authorizations: site owner, water authorities, complicated coordination of different authorities and offices - Vandalism The floodplain area should be wide and not densely constructed to let the water run off easily.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Empty open space at floodplain • Lawns • Dam to defend the background areas These conventional solutions target one or several challenges completed by this NBS. In conventional solutions, floodplains are usually underutilized
Close NBS	• Public urban green spaces • Large urban public parks • Urban forests • Meadows • Infrastructure removed on rivers

IV/ References

IV.1 Scientific and more operational references (presented jointly)
CRYER Russell: Wise use of floodplains - a demonstration of techniques to evaluate and plan floodplain restoration, EC LIFE99 ENV/UK/000203 HUDSON Paul F. and MIDDELKOOP, Hans: Integrated Floodplain Management, Environmental Change and Geomorphology: Problems and Prospects, 2015 Springer New York RURAL ECONOMY AND LAND USE: *Integrated management of floodplains* SEMSWA:, 2018, *Working in the floodplain, http://www.semswa.org/working-in-the-floodplain.aspx* SPARKS, Richard E., BRADEN, John B.: Naturalization of Developed Floodplains: An Integrated Analysis TERRA Alapítvány, 2018.: A Tisza-völgy növényvilága*, http://www.terra.hu/cian/novenyv.html*

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- **On building & structures**
  - **Green roofs**
  - **Green walls**
  - **Vegetated pergola**

- **On buildings & structures**
- **Green roofs**

> **EXTENSIVE GREEN ROOF**

> **INTENSIVE GREEN ROOF**

> **SEMI-NTENSIVE GREEN ROOF**

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing	
Definition	Green roofs serve several purposes for a building, such as absorbing rainwater (Simmons et al., 2008), providing insulation (Alexandri and Jones, 2008), creating a habitat for wildlife (Nagase and Tashiro-Ishii, 2018), increasing benevolence and decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape (Ragheb et al., 2016), and helping to lower urban air temperatures and mitigate the heat island effect (Jin et al., 2018). Extensive green roofs are generally made up of a very thin layer of substrate (from 8 cm to 15 cm) or other planting medium with shallow-root plants like sedum, herbs, mosses, and grasses. This solution requires a minimal maintenance and it normally is not occupied. Often, green roofs substrate is contained by a tray system, which provides a barrier to excessive growth, protects the roof membrane, and interlocks the entire system together to prevent wind damage.  Chicago City Hall Green Roof. *Author:* TonyTheTiger CC BY-SA 3.0

Different variants existing
<u>Three kinds can be identified, depending of the botanical properties:</u>
=> Extensive vegetative cover
They consist of different superimposed layers allowing easy and quick installation of plants on a waterproof roof:

- A carpet of pre-cultivated sedums composed of different varieties of plants.
- Modular system: an irrigation mat controlled by a humidity sensor, designed to bring water when the plant needs it while limiting consumption.

- A retention layer that is used to control the inflow of water during periods of drought.
- A drainage layer, placed directly on the waterproofing of the roof, which allows to evacuating excess water and aerating the roots of plants.

The green roof unfolds like a succession of carpets
© sempergreen

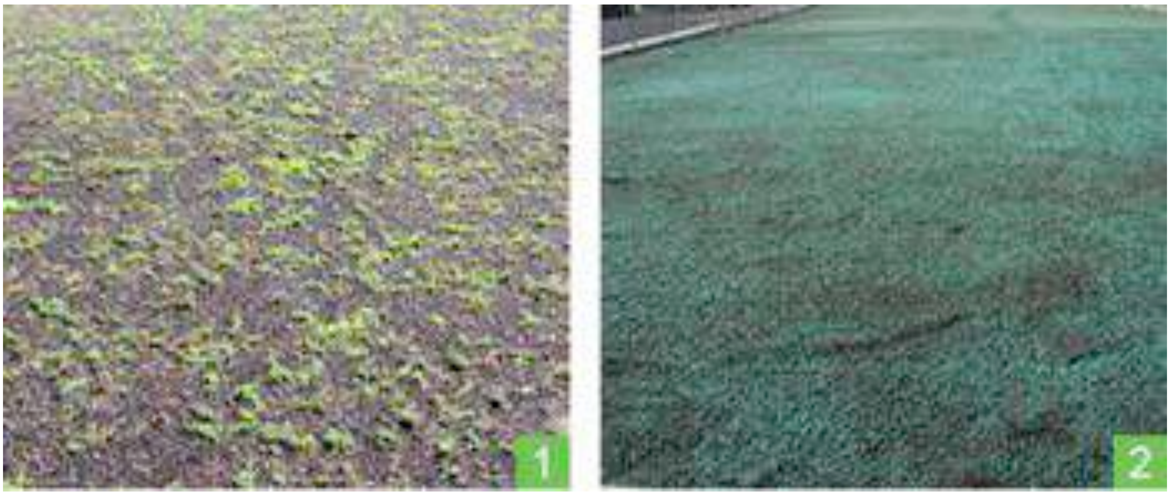
=> Installation in micro-clumps
The planting of clumps or buckets on the roofs makes it possible to diversify the vegetal palette of the green roof. The installation of this revegetation complex is only possible in the spring or autumn to optimize the rooting of the plants in the substrate. The vegetative cover rate reaches 80% after a period of 12 to 24 months.

Micro-clumps used during the extensive green roof installation
© micro-mottes.fr

Plantation of micro-clumps on a green roof
© Le prieuré

=> Fragments or cutting plants
The revegetation complex with seedling fragments is particularly suitable for large-scale projects (more than 1000 m²). Easy and fast to implement, the rate of plant cover reaches 80% after a period of 18 to 36 months. The ultimate appearance of the project depends on good quality planting (distribution of cuttings, rolling and watering after spreading), and also on the care given to maintaining the roof during the phase when the plants are getting established. It is essential to have a water connection on the roof when spreading cuttings. In order to have optimum chance of success, a few essential steps must be taken when planting using the spreading method:

- Obtain the plant cuttings,
- Spread out the cuttings well over the whole of the surface area to be planted,
- Roll the surface area in order to facilitate contact



Aesthetic appearance of a green roof produced by sowing sedum cuttings. 1. Using manual sowing 2. Using gel seeding
© Vegetal I.D.

=> Pre-planted tray plants

This modular system incorporates all the layers of a green roof system (drain, filter, growing medium and plants) grouped together in one unit known as a tray, module or paver
© Vegetal I.D.

It is a is a complete extensive green roof system in a modular tray, ensuring excellent planting quality with simple installation
© Axter

I.2 Urban challenges and sub-challenges related + impacts

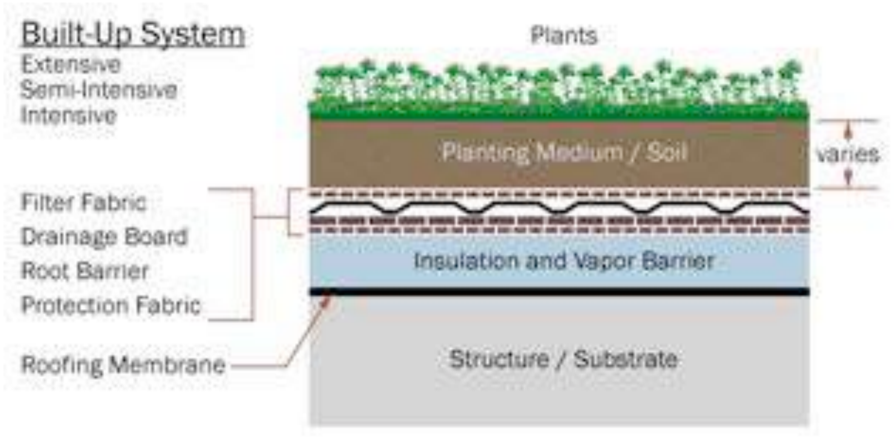
Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality > 02-2 Flood management 07| Public health and well-being > 07-2 Quality of life	- Reduce Storm water Runoff and Combined Sewage Overflows. The most important benefit of green roofs is that they can reduce the amount of rainfall (52% of the total rainfall) and improve the quality of storm-water runoff from a building site, depending on month and soil thickness (Mentens et al., 2006). - Aesthetic and wellbeing. One benefit of green roofs that is not easily quantifiable is the aesthetic improvement that landscape provides. This is especially important where building occupants overlook lower roof areas, which are often barren planes or are full of mechanical equipment.
Co-benefits and challenges foreseen	01| Climate issues - > 01-2 Climate adaptation 04I Urban space and Biodiversity > 04- 1 Biodiversity 5 | Soil management	- Reduce "Urban Heat Island Effect. The natural plantings and soils in green roofs mitigate the heat island effect by better modulating local air temperature

	> 5.1 | Soil management and quality 06| Resource efficiency > 06-1 Food, energy & water 07| Public health and well-being > 07-1 Acoustics	fluctuations by 1 to 2°C caused by radiant heating during the day (Bass et al., 2003). - Green roof substrate can include microarthropods and microbes (Rumble et al., 2018) - Enhancement of architectural interest and biodiversity (Castleton et al., 2010) - The green roof substrate is able to support vegetation. In addition, it can store carbon(Bouzouidja et al., 2018). In addition, it can store carbon. - Green roofs can help reduce energy costs for a building by acting as another layer of insulation between the inside and outside of the roof, - Extend roof life: actually double the life of the waterproofing material 10-20 years to 50 years as it is protected from UV and the chemical damage (Theodosiou, 2009), - Green roofs can also help reduce sound transmission through the roof from outside the building.
Possible negative effects	07| Public Health and well-being > 07-3 Health 10I People security > 10.3 Other: bad structural designs 04| Urban space management	- Plants can affect allergies - Risk of roof structure collapsing. Green roof increases structural load, so that is critical to conduct a structural investigation to determine the building's existing structural load-bearing capacity. It makes green roof **capital cost rise**. - Green roof requires routine landscape maintenance, which can vary from occasional to regular and can add a **significant ongoing cost**.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Buildings and sometimes only partially.
Impacted scales	At building scale and depending on the number of green roofs existing. At neighbourhood or city scale, the impact of green roofs is less relevant. It is depending of green roof area coverage
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	> Tray system: immediately > Build up green roof. depends on the selected plants: · shallow-root plants like sedum, mosses, and grasses: 1 year · flowering plants, taller grasses, and small shrubs: 1 to 2 years · large shrubs and trees: 3 to 5 years
Life time	30-50 years
Sustainability and life cycle	Extensive green roof requires significant interventions to be removed. Moreover, the plants and substrate can be composting or recycling in most of the cases.
Management aspects (kind of interventions + intensity)	- nutrients - minimal maintenance, 1-2 interventions per year
II.3 Stakeholders involved/ social aspects	

Stakeholders involved in the decision process	- Private owners, or co-owners of buildings - Municipality in case of public buildings - Experienced engineers, - Building surveyors, - Property managers
Technical stakeholders & networks	- Landscape architect, planer, designers, - Structural engineers, - Architects - Specialized green spaces management firms and gardeners.
Social aspects	-Necessity to find an agreement with all the co-owner of a building => importance of the participatory process. -Necessity to inform about the real impacts, to reassure about widespread prejudices (risk to keep humidity across the roof, fear to introduce insects in the building, etc.)
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- On a new building or existing one, that needs a structural engineer investigation. - Selection of plant adapted to: • the local climate • Sunlight orientation and overshadowing • Wind exposure - Set up the maintenance keeping plants in the right conditions. - Maintaining services in the right conditions. Care must be taken to keep roots and leaves out of the drainage system
Materials involved	- moisture barrier (roofing membrane) - thermal insulator - waterproofing membrane (root barrier) - drainage layer - filtering layer - growing medium (substrate) - sedum plants most of the time



© Archoolbox

II.5 Legal aspects related

- Ownership and tenant. There is a clear difference between an owner (landlord) and a tenant (lessee). A landlord has exclusive rights to their property to use in any manner according to the planning constraints and permissions in each jurisdiction (and no third-party consent is generally required to create a green roof or wall). A tenant is bound by the terms of their lease, and a green roof or wall may be prohibited or a permissible use with consent. Consent is likely to be required from the landlord (2).
- Structural loads. Analysis by a structural engineer is required (2).
- Irrigation and drainage: Water supply is usually a simple tap, but if irrigation is needed, and a hydraulic engineer is required to review how it is to be serviced and drained and it is likely need irrigation licence (2).
- Access permit to the roof (2)
- Insurance. Insurance will be required by the party maintaining the garden or produce area, as well as insurance for visitors and general public; also liability for work, health and safety legislation (2).

II.6 Funding Economical aspects

Range of cost	Green roof cost range from 25 to 75 $€/m^2$ depending on the distance between the structural material storage (Niu et al., 2010). In addition, Greenery systems can provide an energy saving of about 215 $ $year^{-1}$ depending on regional and climatic conditions (Besir and Cuce, 2018).
Origin of the funds (public, private, public-private, other)	- Private: the ownership is a private as business building, hotels, apartments - Public. The building ownership is a public owner like City councils, museums, schools, etc.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- It is possible de combine green roof system with conventional photovoltaic (PV) solution. A positive influence for this integration: green roof surface and soil temperatures are reduced from the shading and higher power output of PV panel is achieved from the cooling. For a low-rise commercial building, the results indicated that the energy consumption for air conditioning of the integrated system is slightly lower than the stand-alone system and the PV system on integrated approach generates 8.3% more electricity than the stand-a-lone option. (Hui and Chan, 2011).

Green roof and photovoltaic combination

© 2018, International Green Roof Association

- Green roofs provide habitat to many bee species. For example, in New York City, U.S.A., a study of the bee diversity in urban gardens found a total of 54 species from 19 sites (Matteson et al., 2008). In Vancouver city, Canada, gardens and urban parks obtained a total of 56 bee species from 25 sites; species richness did not differ significantly among site types (Tommasi et al., 2004).

Implementation of beehive on a green roof

© 2018 Dusty Gedge's Roofs & Rambles

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Green Roof Goal: It is essential to start project planning with the purpose of the green roof. Is it intended primarily to deliver environmental, cost-saving benefits? Is it expected to serve as a decorative landscape element? Is it for urban farming? To set the direction for any project, first define the purpose of the green roof, establish priorities for specific goals and align stakeholder expectations (Rugh, 2014) - Architectural Factors: Roof structural load capacity is the most basic issue (Rowe et al., 2003) Location: Regional climate determines what type of green roof and plants you can and should have (Rowe et al., 2003).
Limiting factors	- Take into account **the new structural load** when refurbishing a building: One important item to be considered is the increased structural load. The structural engineer must factor in the weight of completely saturated soil since the plantings and the soil will hold a significant amount of water (1).  City University of Hong Kong Hu Fa Kuang Sports Centre roof collapses site Author: exploringlife-CC BY-SA 4.0 - **Lifetime of the roof membrane.** Green roofs tend to improve the life of the membrane because it is completely covered by plantings and is not exposed to the sun's harsh UV rays. However, the membrane may be exposed to plant roots, animals and insects, and fertilizer chemicals. It is important that a protective barrier be used over the waterproofing membrane. - **Maintenance ongoing cost is also important to consider** that a green roof requires routine landscape maintenance, which can vary from occasional to regular and can add a significant ongoing cost. In addition, space should be allocated for storage of maintenance materials
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- White or cool roof: the green roof decreases the annual building needs for heating and cooling by 1.2% while the white roof contributes to decrease the needs just by 0.4%. This small difference is mainly attributed to the higher insulation capacity of the green roof and the lower calculated surface temperatures on it (Santamouris, 2014)

	 White or light-colored roofs © NREL/CRAIG MILLER PRODUCTIONS/DOE - Gravel roof: The gravel in a ballasted roof helps absorb heat, preventing the sun from heating the roof materials below and making the roof more energy-efficient. In addition, gravel also protects against hail and from foot traffic during repair or maintenance work. The gravel is easy to move when conducting repairs or maintenance  Gravel roof © Anderson Roofing
Close NBS	• Other green roof types (semi-intensive and intensive green roof) • Build or attached planter systems (including balconies)

IV/ References

Nota: references presented below are often common with the whole category Vertical structures "Green walls & façades".

IV.1 Scientific and more operational references (presented jointly)

Alexandri, E., Jones, P., 2008. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. Build. Environ. 43, 480–493.

Bass, B., Liu, K., Baskaran, B., 2003. Evaluating rooftop and vertical gardens as an adaptation strategy for urban areas.

Besir, A.B., Cuce, E., 2018. Green roofs and facades: A comprehensive review. Renew. Sustain. Energy Rev. 82, 915–939.

Castleton, H.F., Stovin, V., Beck, S.B.M., Davison, J.B., 2010. Green roofs; building energy savings and the potential for retrofit. Energy Build. 42, 1582–1591. https://doi.org/10.1016/j.enbuild.2010.05.004

Hui, S.C., Chan, S., 2011. Integration of green roof and solar photovoltaic systems, in: Joint Symposium. pp. 1–12.

Jin, C., Bai, X., Luo, T., Zou, M., 2018. Effects of green roofs' variations on the regional thermal

environment using measurements and simulations in Chongqing, China. Urban For. Urban Green. 29, 223–237.
Matteson, K.C., Ascher, J.S., Langellotto, G.A., 2008. Bee richness and abundance in New York City urban gardens. Ann. Entomol. Soc. Am. 101, 140–150.
Mentens, J., Raes, D., Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landsc. Urban Plan. 77, 217–226.
Nagase, A., Tashiro-Ishii, Y., 2018. Habitat template approach for green roofs using a native rocky sea coast plant community in Japan. J. Environ. Manage. 206, 255–265.
Ragheb, A., El-Shimy, H., Ragheb, G., 2016. Green architecture: a concept of sustainability. Procedia-Soc. Behav. Sci. 216, 778–787.
Rowe, D.B., Rugh, C.L., VanWoert, N., Monterusso, M.A., Russell, D.K., 2003. Green roof slope, substrate depth, and vegetation influence runoff, in: Proceedings of the 1st North American Green Roof Conference: Greening Rooftops for Sustainable Communities. The Cardinal Group, Chicago. pp. 354–362.
Rugh, C.L., 2014. Critical Success Factors for Green Roof Projects. Roof. Contract. Mag.
Rumble, H., Finch, P., Gange, A.C., 2018. Green roof soil organisms: Anthropogenic assemblages or natural communities? Appl. Soil Ecol. 126, 11–20. https://doi.org/10.1016/j.apsoil.2018.01.010
Santamouris, M., 2014. Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Sol. Energy 103, 682–703.
Simmons, M.T., Gardiner, B., Windhager, S., Tinsley, J., 2008. Green roofs are not created equal: the hydrologic and thermal performance of six different extensive green roofs and reflective and non-reflective roofs in a sub-tropical climate. Urban Ecosyst. 11, 339–348. https://doi.org/10.1007/s11252-008-0069-4
Theodosiou, T., 2009. Green roofs in buildings: Thermal and environmental behaviour. Adv. Build. Energy Res. 3, 271–288.
Tommasi, D., Miro, A., Higo, H.A., Winston, M.L., 2004. Bee diversity and abundance in an urban setting. Can. Entomol. 136, 851–869.

IV.2 Sources used in this factsheet

1. Archoolbox, architect’s technical reference. https://www.archtoolbox.com/materials-systems/site-landscape/green-roofs.html

2. Green roofs and walls, RICS guidance note, Australia (April 2016) Published by the Royal Institution of Chartered Surveyors (RICS)

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I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition

Roofs do not all have the same carrying capacity, therefore depending on the structures, and the type of plantation must be adapted. Intensive green roofs (living roof) are those with the more substrate, usually with a total thickness starting by app. 20 to 200 cm, therefore the stress imposed on the structure is very large. Usually, either roofs that have an intensive green roof were planned to accommodate the green roof at the time of the construction of the building or there have been structure reinforcement works. An intensive green roof weighs from 170 kg m^{-2} to over 970 kg m^{-2}, then given the large amount of soil, plant options are extremely large, ranging from shrubs to urban agriculture to trees.(32) Since the plants are large gauges, it requires an irrigation system and major maintenance. Often, intensive green roofs can serve as parks open to the public.

Intensive green roof, Vancouver Public Library (Photo: Terri Meyer Boake B.E.S. B.Arch. M. Arch., Université de Waterloo)

Different variants existing

Two kinfs can be identified, depending on the plant properties and the height of plants:

=> Recreation rooftop or roof garden

The philosophy of a roof garden relies on the fact that the plant material that is destroyed during the construction phase will be restored at the top of the building and will reduce the adverse effects of urbanization and deforestation (Osmundson, 1999). The characteristics of a good crop is used for the roof garden is resistant to exposure to direct sunlight.

It is important to note given the location of the plant growth will have a shorter distance to the sun than usual garden. Also, avoid plants that have roots growing down. The contribution of roof gardens to the urban environment is manifold. It has been established that roof gardens reduce temperature and solar irradiance, provide up to 50% reduction in the heat flux into building (Onmura et al., 2001). Thus resulting in significant building energy saving. In addition, roof gardens contribute to the Urban Heat Effect mitigation (Osmundson, 1999), protect and secure the longevity of the roof structure, grade rainstorm water distribution (Nektarios et al., 2011).

Blackfriars House roof garden in Manchester © Jamie Boulger

=> Roof terrace garden

Roof terraces are designed specifically for recreation, although the inclusion of vegetation in planters (such as on terraces or balconies) is often used to enhance their visual attractiveness. Roof terraces are those that have no substrate and no intentionally vegetated part to their construction. Because of this, they have limited SUDS (sustainable urban drainage systems) or climate change adaptation benefit (Authority, 2008). Roof terraces, where there is adequate space available, are well suited for sports such as ball games.

The Orchid Hotel, Beijing, China
© Tripadvisor (link)

Clubhouse Mongkok Skypark / concrete, Mong Kok, Hong Kong
© Manufacturers Fritz Hansen, HAY, Tom Dixon, Vitra, e15, Carl Hansen, Marset, Droog, De La Espada, Kasthall

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-2 Climate adaptation 02| Urban water management and quality > 02-1 Urban water management > 02-2 Flood management 3 | Air quality > 3.2 | Air quality locally 07| Public health and well-being > 07-2 Quality of life > 07-3 Health	- The tree canopy reduces solar radiation reaching the roof surface (Jim and Tsang, 2011) - (Berndtsson et al., 2009) studying intensive roof (in Japan) constructed with inorganic light weight soil found that the green roof contributed to the substantial decrease of total nitrogen in runoff - German studies from 1987 to 2003 as summarized by (Mentens et al., 2006) report that intensive green roofs showed annual runoff Reduction being equal 85–65% of annual precipitation (100%) - Air pollution due to the polymer production process can be balanced by green roofs in 13e32 year (Bianchini and

		Hewage, 2012) - Intensive green roofs produce a remarkable aesthetic improvement, especially important for surrounding buildings.
Co-benefits and challenges foreseen	06| Resource efficiency > 06-1 Food, energy & water 04l. Urban space and Biodiversity > 04-1 Biodiversity 5 | Soil management > 5.1 | Soil management and quality 7 | Public health and well-being > 07-1 Acoustics  Greenery seems to be taking over the roof of one building in lower Manhattan. Author: Alyson Hurt, CC-by-2.0	- The surface temperature of the green roof is found to be up to 15°C lower than that of a conventional roof (Karachaliou et al., 2016), decreasing buildings energy consumption. - Green roofs could provide equivalent habitat value to many urban insects, and thus an opportunity to increase and manage their associated ecosystem services, in combination with habitat space at ground-level (MacIvor and Lundholm, 2011) - Green roofs act as habitats for native plants species in urban landscape.(Madre et al., 2014) - The green roof substrate is able to support vegetation. In addition, it can store carbon(Bouzouidja et al., 2018). In addition, it can store carbon. - Green roofs decrease sound propagation.
Possible negative effects	07| Public Health and well-being > 07-3 Health 10l People security > 10.3 Other: bad structural designs 04| Urban space management	- The higher consumed level of energy for green roof maintenance (Carpenter and Zhou, 2013) - The concentration on the economical aspect of green roofs in the present green roof situation undermines the opportunities in ecology and society (Pedersen, 2014)

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Buildings and sometimes only partially
Impacted scales	At building scale and depending on the number of green roofs existing. At neighbourhood or city scale, the impact of green roofs is less relevant. It is depend of green roof area coverage
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	> Build up green roof depends on the selected plants and/or tree: · flowering plants, herbs, taller grasses, and small shrubs: 1 to 2 years · large shrubs and trees: 3 to 5 years > Can be immediately ready (e.g., if you plant large trees and/or a turf lawn). Most of time, the customer of an intensive green roof want to use it immediately
Life time	30-50 years
Management aspects (kind of interventions + intensity)	- Does require irrigation - Nutrients - Maximal maintenance, at least 2, but depending on the intensity of plants (e.g., if there is a lawn, you have to mow it nearly weekly in summer if customer want that aesthetic). Maintenance can be like in garden, very intensive. - Range from weekly checks during summer on an intensive roof garden

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Private owners, or co-owners of buildings - Municipality in case of public buildings - Experienced engineers, - Building surveyors, - Property managers
Technical stakeholders & networks	- Landscape architect, planer, designers, - Structural engineers, - Architects - Specialized green spaces management firms and gardeners.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Decision between the type of use to which it is put; an occupied roof or not occupied roof garden design - On a new building or existing one, that needs a structural engineer investigation. - Selection of plant adapted to: • the local climate • Sunlight orientation and overshadowing • Wind exposure - Set up the maintenance keeping plants in the right conditions. - Maintaining services in the right conditions. Care must be taken to keep roots and leaves out of the drainage system
Materials involved	- moisture barrier (roofing membrane) - thermal insulator - waterproofing membrane (root barrier) - drainage layer - filtering layer - growing medium (substrate) - sedum plants most of the time

II.5 Legal aspects related

- Ownership and tenant. There is a clear difference between an owner (landlord) and a tenant (lessee). A landlord has exclusive rights to their property to use in any manner according to the planning constraints and permissions in each jurisdiction (and no third-party consent is generally required to create a green roof or wall). A tenant is bound by the terms of their lease, and a green roof or wall may be prohibited or a permissible use with consent. Consent is likely to be required from the landlord (1).
- Structural loads. Analysis by a structural engineer is required (1).
- Irrigation and drainage: Water supply is usually a simple tap, but if irrigation is needed, and a hydraulic engineer is required to review how it is to be serviced and drained and it is likely need irrigation licence (1).
- Access permit to the roof (1)
- Insurance. Insurance will be required by the party maintaining the garden or produce area, as well as insurance for visitors and general public; also liability for work, health and safety legislation (1).

II.6 Funding Economical aspects

Range of cost	Calculating the average cost of green roofs can be difficult because there a number of variables, not just the size and accessibility of the site but the types of plants that are going to be grown on it. In the United Kingdom one can expect to pay around 100 €/m^2. In addition to the initial cost of designing and installing green roofs, there are also running costs, which need to be taken into consideration, such as maintenance and regular gardening. The cost of a standard intensive green roof in Britania, Canada, starts around 340€ m^{-2} (Bianchini and Hewage, 2012) Green roof components: · Substrate

	· Plants · Filter fabric · Drainage Board · Root barriers · Protection fabric Irrigation system Drainage system
Origin of the funds (public, private, public-private, other)	- Private: the ownership is a private as business building, hotels, apartments - Public. The building ownership is a public owner like City councils, museums, schools, etc.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Green roofs provide habitat to many bee species. For example, in New York City, U.S.A., a study of the bee diversity in urban gardens found a total of 54 species from 19 sites (Matteson et al., 2008). In Vancouver city, Canada, gardens and urban parks obtained a total of 56 bee species from 25 sites; species richness did not differ significantly among site types (Tommasi et al., 2004).

Implementation of beehive on a green roof
© 2018 Dusty Gedge's Roofs & Rambles

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors

- **Green Roof Goal**: It is essential to start project planning with the purpose of the green roof. Is it intended primarily to deliver environmental, cost-saving benefits? Is it expected to serve as a decorative landscape element? Is it for urban farming? To set the direction for any project, first define the purpose of the green roof, establish priorities for specific goals and align stakeholder expectations (Rugh, 2014).
- **Architectural Factors**: Roof structural load capacity is the most basic issue (Rowe et al., 2003)

Location: Regional climate determines what type of green roof and plants you can and should have (Rowe et al., 2003).

Limiting factors	- Take into account the new structural load when refurbishing a building: One important item to be considered is the increased structural load. The structural engineer must factor in the weight of completely saturated soil since the plantings and the soil will hold a significant amount of water (1).

City University of Hong Kong Hu Fa Kuang Sports Centre roof collapses site

Author: exploringlife-CC BY-SA 4.0

- **Lifetime of the roof membrane.** Green roofs tend to improve the life of the membrane because it is completely covered by plantings and is not exposed to the sun's harsh UV rays. However, the membrane may be exposed to plant roots, animals and insects, and fertilizer chemicals. It is important that a protective barrier be used over the waterproofing membrane.
- **Maintenance ongoing cost. is also important to consider** that a green roof requires routine landscape maintenance, which can vary from occasional to regular and can add a significant ongoing cost. In addition, space should be allocated for storage of maintenance materials

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart

- White or cool roof: the green roof decreases the annual building needs for heating and cooling by 1.2% while the white roof contributes to decrease the needs just by 0.4%. This small difference is mainly attributed to the higher insulation capacity of the green roof and the lower calculated surface temperatures on it (Santamouris, 2014)

White or light-colored roofs

© NREL/CRAIG MILLER PRODUCTIONS/DOE

- Gravel roof: The gravel in a ballasted roof helps absorb heat, preventing the sun from heating the roof materials below and making the roof more energy-efficient. In addition, gravel also protects against hail and from foot traffic during repair or maintenance work. The gravel is easy to move when conducting repairs or maintenance

	 Gravel roof © Anderson Roofing
Close NBS	- Other green roof types (semi-intensive and extensive green roof) - Build or attached planter systems (including balconies)

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Authority, G.L., 2008. Living Roofs and Walls: Technical Report Supporting London Plan Policy (Technical Report).
Berndtsson, J.C., Bengtsson, L., Jinno, K., 2009. Runoff water quality from intensive and extensive vegetated roofs. Ecol. Eng. 35, 369–380.
Bianchini, F., Hewage, K., 2012. How “green” are the green roofs? Lifecycle analysis of green roof materials. Build. Environ. 48, 57–65.
Carpenter, J., Zhou, J., 2013. Life cycle analysis of a St. Louis flat roof residential retrofit for improved energy efficiency, in: ICSDEC 2012: Developing the Frontier of Sustainable Design, Engineering, and Construction. pp. 20–28.
Jim, C.Y., Tsang, S., 2011. Biophysical properties and thermal performance of an intensive green roof. Build. Environ. 46, 1263–1274.
Karachaliou, P., Santamouris, M., Pangalou, H., 2016. Experimental and numerical analysis of the energy performance of a large scale intensive green roof system installed on an office building in Athens. Energy Build. 114, 256–264.
MacIvor, J.S., Lundholm, J., 2011. Insect species composition and diversity on intensive green roofs and adjacent level-ground habitats. Urban Ecosyst. 14, 225–241.
Madre, F., Vergnes, A., Machon, N., Clergeau, P., 2014. Green roofs as habitats for wild plant species in urban landscapes: first insights from a large-scale sampling. Landsc. Urban Plan. 122, 100–107.
Matteson, K.C., Ascher, J.S., Langellotto, G.A., 2008. Bee richness and abundance in New York City urban gardens. Ann. Entomol. Soc. Am. 101, 140–150.
Mentens, J., Raes, D., Hermy, M., 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landsc. Urban Plan. 77, 217–226.
Nektarios, P.A., Amountzias, I., Kokkinou, I., Ntoulas, N., 2011. Green roof substrate type and depth affect the growth of the native species Dianthus fruticosus under reduced irrigation regimens. HortScience 46, 1208–1216.
Onmura, S., Matsumoto, M., Hokoi, S., 2001. Study on evaporative cooling effect of roof lawn gardens. Energy Build. 33, 653–666. http://dx.doi.org/10.1016/S0378-7788(00)00134-1
Osmundson, T., 1999. Roof gardens: history, design, and construction. WW Norton & Company.
Pedersen, K.L., 2014. Green roofs for sustainable urban development: the Oslo case study (Master’s Thesis). Norwegian University of Life Sciences, \AAs.
Rowe, D.B., Rugh, C.L., VanWoert, N., Monterusso, M.A., Russell, D.K., 2003. Green roof slope, substrate depth, and vegetation influence runoff, in: Proceedings of the 1st North American Green Roof Conference: Greening Rooftops for Sustainable Communities. The Cardinal Group, Chicago. pp. 354–362.
Rugh, C.L., 2014. Critical Success Factors for Green Roof Projects. Roof. Contract. Mag.
Santamouris, M., 2014. Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Sol. Energy 103, 682–703.
Tommasi, D., Miro, A., Higo, H.A., Winston, M.L., 2004. Bee diversity and abundance in an urban setting. Can. Entomol. 136, 851–869.

IV.2 Sources used in this factsheet

1. Archoolbox, architect's technical reference. https://www.archtoolbox.com/materials-systems/site landscape/green-roofs.html

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> SEMI INTENSIVE GREEN ROOF

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition

A semi-intensive green roof system is characterized by small herbaceous plants, ground covers, grasses and small shrubs, requiring moderate maintenance and occasional irrigation. A typical growing medium depth for a semi-intensive green roof is 15 to 30 cm. This system is able to retain more storm water than an extensive system and provides the potential to host a richer ecology. Though higher in maintenance, this green roof system also provides the potential for a formal and intensive garden effect. In addition, few references identify a third category of green roofs: simple-intensive (semi-intensive) (FLL, 2008) which are vegetated with lawns and ground covering plants. These roofs require frequent maintenance including cutting, watering, and fertilization.

Semi-intensive green roof, Carnegie Mellon Hamerschlag Hall
© GREEN ROOF SERVICE LLC

Different variants existing

It is difficult to identify a variants of semi-intensive green roof. According to our expertize, we estimated that there is two kinds of semi-intensive green roof that can be identified like intensive green roof. We founded that they are depended on biodiversity and wide range of different shrubs and habitats:

=> Maintain biodiversity

The philosophy of a semi-intensive green roof relies on the fact that the plant material that is destroyed during the construction phase will be restored at the top of the building and will reduce the adverse effects of urbanization and deforestation (Osmundson, 1999). The characteristics of a good crop is used for this kind of roof is resistant to exposure to direct sunlight.

It is important to note given the location of the plant growth will have a shorter distance to the sun than usual roof. Also, avoid plants that have roots growing down. The contribution of the semi-intensive green roof to the urban environment is manifold.

Those roofs with small or lager shrubs, soil forms the basic constituent of the substrate, in order to support plant growth.

Semi-intensive green roof, Swarthmore College, PA, USA
© greenroofservice.com

Plants development in semi-intensive green roof, Vienna, Austria
© Florian Kraus, Green4cities

Plants development in semi-intensive green roof, Vienna, Austria
© Florian Kraus, Green4cities

Plants development in semi-intensive green roof, Vienna, Austria
© Florian Kraus, Green4cities

=> An ideal habitat

Semi-intensive green roof are designed specifically for recreation, although the inclusion of vegetation in planters (such as on terraces or balconies) is often used to enhance their visual attractiveness. They are those that have no substrate and no intentionally vegetated part to their construction. Because of this, they have limited SUDS (sustainable urban drainage systems) or climate change adaptation benefit (Authority, 2008). Roof terraces, where there is adequate space available, are well suited for sports such as ball games.

The Orchid Hotel, Beijing, China
© Tripadvisor (link)

Blackfriars House roof garden in Manchester
© Jamie Boulger

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-2 Climate adaptation 02| Urban water management and quality > 02-1 Urban water management > 02-2 Flood management 07| Public health and well-being > 07-2 Quality of life	- The plants reduce solar radiation reaching the roof surface then its temperature. It contribute to urban heat island mitigation. - It has been established that semi-intensive green roof reduce temperature and solar irradiance, provide up to 50% reduction in the heat flux into building (Onmura et al., 2001). Thus resulting in significant building energy saving. - Semi-intensive green roof contribute to the Urban Heat Effect mitigation (Osmundson, 1999), protect and secure the longevity of the roof structure, grade rainstorm water distribution (Nektarios et al., 2011) - In the summer months, the semi-intensive systems with grass retained 99% of the load of Pb, Zn, and Cu and 98% of Cd in the water. In winter months the semi-intensive roof with vegetation retained 68% Cu, 92% Zn, 88% Cd 94% Pb in the water (Steusloff, 1998). - Semi-Intensive green roofs produce an aesthetic improvement, especially important for surrounding buildings. - They increase water-holding capacity, and provide sufficient anchorage to the plants (FLL, 2008)
Co-benefits and challenges foreseen	04I. Urban space and Biodiversity > 04-1 Biodiversity 5 | Soil management > 5.1 | Soil management and quality 06| Resource efficiency > 06-1 Food, energy & water 7 | Public health and well-being > 07-1 Acoustics	- Semi-intensive act as habitats for native plants species in urban landscape (Madre et al., 2014) - The green roof substrate is able to support vegetation. In addition, it can store carbon(Bouzouidja et al., 2018). In addition, it can store carbon. - The U values for a semi-intensive green roof with 40 cm soil substrate were 0.45 $W/m^2/K^1$ and 0.61 $W/m^2/K^1$ for a typical roof (Wong et al., 2003). – Adaptive semi-intensive green roof systems are also related to the thermal performance of buildings that is expected to improve in proportion to the increase of the substrate depth (Wong et al., 2003). - A straightforward effect is the decreased sound propagation through the roof system to the inside of the building (Kang et al., 2009).

Possible negative effects	07| Public Health and well-being - 07-3 Health 10I People security - 10.3 Other: bad structural designs 04| Urban space management	- Potential challenges can include structural considerations, issues associated with installing a green roof on a historic building, knowledge of applicable codes, and issues associated with roof construction and maintenance (GSA, 2011). - Green roofs occasionally fail to perform at the level for which they were designed. Potential failures include leaks, plant loss, inadequate drainage, soil erosion and slope instability (GSA, 2011).

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Buildings and sometimes only partially
Impacted scales	At building scale and depending on the number of green roofs existing. At neighbourhood or city scale, the impact of green roofs is less relevant. It is depending of green roof area coverage
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	- Build up green roof. Depends on the selected plants and/or tree: · shallow-root plants like sedum, mosses, herbs, and grasses: 1 year · flowering plants, taller grasses, small and larger shrubs: 1 to 2 years
Life time	30-50 years
Sustainability and life cycle	- Green roofs require significant interventions to be removed and most of the materials can be reused. - Plants and substrate can be composting or recycling in most of the cases.
Management aspects (kind of interventions + intensity)	- Does partially require irrigation - Nutrients - Range from weekly checks during summer on roof terrace garden - The aesthetical approach prevails on simple-intensive green roofs. Maximal maintenance, 8 to over 15 min/m^2/year (Catalano et al., 2018)
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Private owners, or co-owners of buildings - Municipality in case of public buildings - Experienced engineers, - Building surveyors, - Property managers
Technical stakeholders & networks	- Landscape architect, planer, designers, - Structural engineers, - Architects - Specialized green spaces management firms and gardeners.
Social aspects	-Need to find an agreement with all the co-owner of a building => importance of the participatory process. -Need to inform about the real impacts, to reassure about widespread prejudices (risk to keep humidity across the roof, fear to introduce insects in the building, etc.)

II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Decision between the types of use to which it is put: an occupied roof (to access the roof) or not occupied roof (inaccessible to the public). - From technical point of view, semi-intensive green roof can include inverted roof. Often a problem with this type of roof is that there is rainwater sitting underneath inverted roofs. - On a new building or existing one, that needs a structural engineer investigation. - Selection of plant adapted to: • the local climate • Sunlight orientation and overshadowing • Wind exposure - Set up the maintenance keeping plants in the right conditions. - Maintaining services in the right conditions. Care must be taken to keep roots and leaves out of the drainage system
Materials involved	- moisture barrier (roofing membrane) - thermal insulator - waterproofing membrane (root barrier) - drainage layer - filtering layer - growing medium (substrate) - shrubs most of the time

II.5 Legal aspects related

- Ownership and tenant. There is a clear difference between an owner (landlord) and a tenant (lessee). A landlord has exclusive rights to their property to use in any manner according to the planning constraints and permissions in each jurisdiction (and no third-party consent is generally required to create a green roof or wall). A tenant is bound by the terms of their lease, and a green roof or wall may be prohibited or a permissible use with consent. Consent is likely to be required from the landlord (1).
- Structural loads. Analysis by a structural engineer is required (1).
- Irrigation and drainage: Water supply is usually a simple tap, but if irrigation is needed, and a hydraulic engineer is required to review how it is to be serviced and drained and it is likely need irrigation licence (1).
- Access permit to the roof (1)

  Insurance. Insurance will be required by the party maintaining the garden or produce area, as well as insurance for visitors and public; also liability for work, health and safety legislation (1).

II.6 Funding Economical aspects	
Range of cost	Calculating the average cost of green roofs can be difficult because there a number of variables, not just the size and accessibility of the site but the types of plants that are going to be grown on it. In the United Kingdom costs start by approximatively 75 €/m^2. In addition to the initial cost of designing and installing green roofs, there are also running costs, which need to be taken into consideration, such as maintenance and regular gardening. The cost of a semi-intensive green roof in Great Britain, starts around 120 €/m^2. Green roof components: · Substrate · Plants · Filter fabric · Drainage Board · Root barriers · Protection fabric Irrigation system Drainage system

Origin of the funds (public, private, public-private, other)	- Private: the ownership is a private one as business building, hotels, apartments - Public. The building ownership is a public owner like City councils, museums, schools, etc.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Green roofs provide habitat to many bee species. For example, in New York City, U.S.A., a study of the bee diversity in urban gardens found a total of 54 species from 19 sites (Matteson et al., 2008). In Vancouver city, Canada, gardens and urban parks obtained a total of 56 bee species from 25 sites; species richness did not differ significantly among site types (Tommasi et al., 2004).

Implementation of beehive on a green roof
© 2018 Dusty Gedge's Roofs & Rambles

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors

- **Green Roof Goal**: It is essential to start project planning with the purpose of the green roof. Is it intended primarily to deliver environmental, cost-saving benefits? Is it expected to serve as a decorative landscape element? Is it for urban farming? To set the direction for any project, first define the purpose of the green roof, establish priorities for specific goals and align stakeholder expectations (Rugh, 2014).
- **Architectural Factors**: Roof structural load capacity is the most basic issue (Rowe et al., 2003)
Location: Regional climate determines what type of green roof and plants you can and should have (Rowe et al., 2003).

Limiting factors	- Take into account the new structural load when refurbishing a building: One important item to be considered is the increased structural load. The structural engineer must factor in the weight of completely saturated soil since the plantings and the soil will hold a significant amount of water (1).

City University of Hong Kong Hu Fa Kuang Sports Centre roof collapses site

Author: exploringlife-CC BY-SA 4.0

- **Lifetime of the roof membrane.** Green roofs tend to improve the life of the membrane because it is completely covered by plantings and is not exposed to the sun's harsh UV rays. However, the membrane may be exposed to plant roots, animals and insects, and fertilizer chemicals. It is important that a protective barrier be used over the waterproofing membrane.
- **Maintenance ongoing cost. Is also important to consider** that a green roof requires routine landscape maintenance, which can vary from occasional to regular and can add a significant ongoing cost. In addition, space should be allocated for storage of maintenance materials

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart

- White or cool roof: the green roof decreases the annual building needs for heating and cooling by 1.2% while the white roof contributes to decrease the needs just by 0.4%. This small difference is mainly attributed to the higher insulation capacity of the green roof and the lower calculated surface temperatures on it (Santamouris, 2014)

White or light-colored roofs

© NREL/CRAIG MILLER PRODUCTIONS/DOE

- Gravel roof: The gravel in a ballasted roof helps absorb heat, preventing the sun from heating the roof materials below and making the roof more energy-efficient. In addition, gravel also protects against hail and from foot traffic during repair or maintenance work. The gravel is easy to move when conducting repairs or maintenance

	 Gravel roof © Anderson Roofing
Close NBS	- Other green roof types (extensive and intensive green roof) - Build or attached planter systems (including balconies)

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Authority, G.L., 2008. Living Roofs and Walls: Technical Report Supporting London Plan Policy (Technical Report).

Bouzouidja, R., Rousseau, G., Galzin, V., Claverie, R., Lacroix, D., Séré, G., 2018. Green roof ageing or Isolatic Technosol's pedogenesis? J. Soils Sediments 18, 418–425. https://doi.org/10.1007/s11368-016-1513-3

Catalano, C., Laudicina, V.A., Badalucco, L., Guarino, R., 2018. Some European green roof norms and guidelines through the lens of biodiversity: Do ecoregions and plant traits also matter? Ecol. Eng. 115, 15–26. https://doi.org/10.1016/j.ecoleng.2018.01.006

FLL, F.L.L., 2008. Guidelines for the Planning, Construction, and Maintenance of Green-roof Sites.

GSA, U., 2011. The Benefits and Challenges of Green Roofs on Public and Commercial Buildings. Rep. U. S. Gen. Serv. Adm.

Kang, J., Huang, H., Sorrill, J., 2009. Experimental study of the sound insulation of semi-extensive green roofs, in: INTER-NOISE and NOISE-CON Congress and Conference Proceedings. Institute of Noise Control Engineering, pp. 2817–2823.

Madre, F., Vergnes, A., Machon, N., Clergeau, P., 2014. Green roofs as habitats for wild plant species in urban landscapes: first insights from a large-scale sampling. Landsc. Urban Plan. 122, 100–107.

Matteson, K.C., Ascher, J.S., Langellotto, G.A., 2008. Bee richness and abundance in New York City urban gardens. Ann. Entomol. Soc. Am. 101, 140–150.

Nektarios, P.A., Amountzias, I., Kokkinou, I., Ntoulas, N., 2011. Green roof substrate type and depth affect the growth of the native species Dianthus fruticosus under reduced irrigation regimens. HortScience 46, 1208–1216.

Onmura, S., Matsumoto, M., Hokoi, S., 2001. Study on evaporative cooling effect of roof lawn gardens. Energy Build. 33, 653–666. http://dx.doi.org/10.1016/S0378-7788(00)00134-1

Osmundson, T., 1999. Roof gardens: history, design, and construction. WW Norton & Company.

Rowe, D.B., Rugh, C.L., VanWoert, N., Monterusso, M.A., Russell, D.K., 2003. Green roof slope, substrate depth, and vegetation influence runoff, in: Proceedings of the 1st North American Green Roof Conference: Greening Rooftops for Sustainable Communities. The Cardinal Group, Chicago. pp. 354–362.

Rugh, C.L., 2014. Critical Success Factors for Green Roof Projects. Roof. Contract. Mag.

Santamouris, M., 2014. Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Sol. Energy 103, 682–703.

Steusloff, S., 1998. Input and output of airborne aggressive substances on green roofs in Karlsruhe, in: Urban Ecology. Springer, pp. 144–148.

Tommasi, D., Miro, A., Higo, H.A., Winston, M.L., 2004. Bee diversity and abundance in an urban setting. Can. Entomol. 136, 851–869.

Wong, N.H., Chen, Y., Ong, C.L., Sia, A., 2003. Investigation of thermal benefits of rooftop garden in the tropical environment. Build. Environ. 38, 261–270.

IV.2 Sources used in this factsheet

1. Archoolbox, architect's technical reference. https://www.archtoolbox.com/materials-systems/site landscape/green-roofs.html

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- On buildings & structures
- Green walls

> CLIMBER GREEN WALL

> GREEN WALL SYSTEM

> PLANTER GREEN WALL

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	This NBS type is about the use of self-climbing plants to cover walls and façades. By this characteristic type, the plant is directly rooted into soil. This is the easiest, cheapest and most efficient way for greening walls and buildings with a long tradition and history back to ancient times (Ottelle, 2011).

Different variants existing

Two main types can be identified, which further split up depending on the botanical properties:

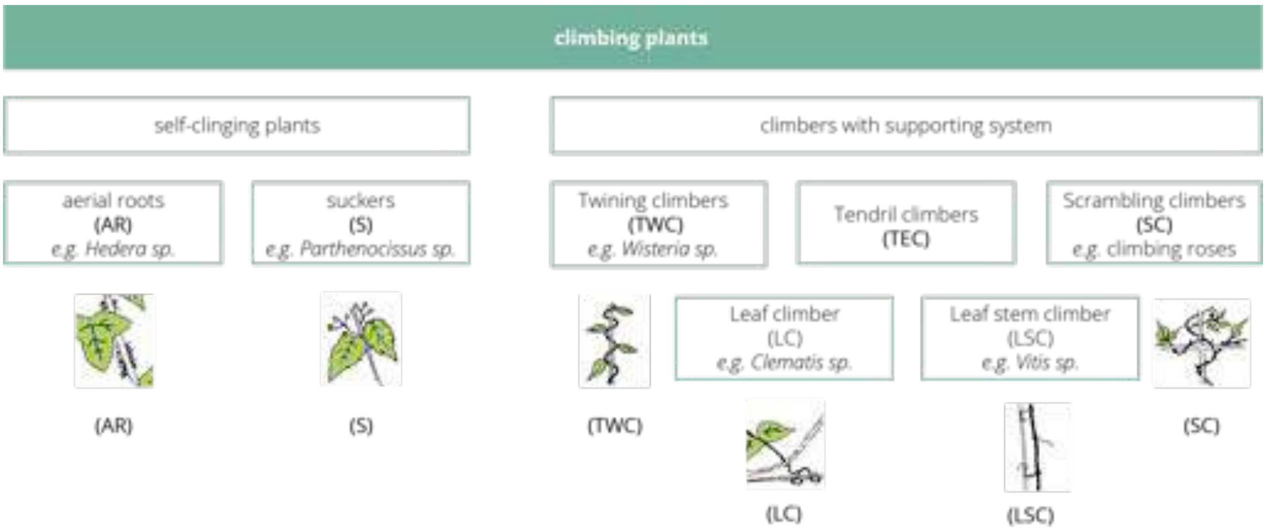
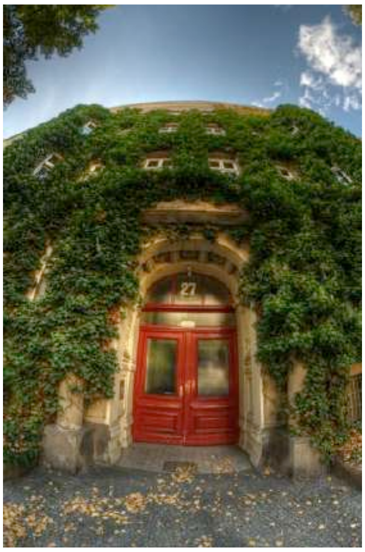


Fig.: Classification of climbing plants growth form according to FLL 2000 (MA 22 2018)

=> Self-clinging climbers
Self-clinging plants do not need any climbing support, because they are growing by themselves with the support of aerial roots (e.g. *Hedera helix*) or suckers (*Parthenocissus sp.).*



Hedera helix (ivy)
© Green4Cities

Parthenocissus tricuspidata
(Boston ivy) © Green4Cities

Aerial roots *Hedera helix*
© Green4Cities

Sucker discs *Parthenocissus tricuspidata* © Green4Cities

=> Climbers with supporting system
These climbing plants require a climbing assistance on the building/structure, to climb and hold on it. There are existing supporting systems for nearly any growth form. The climbing assistance have to be adjusted for the right kind of plant.

Climbing plants on a structure
© Green4Cities

MFO-Park Zurich
© Green4Cities

Different climbing plants on a facade
© MA22

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 07| Public Health and well-being > 07.-2 Quality of life	- Shade building, reduce the heating of walls - Do not contribute to warm air and degrade comfort. Cool surface - Comfort/Aesthetic value - Contact with nature - Support for education
Co-benefits and challenges foreseen	03| Air quality issues 04| Biodiversity and Urban Space > 04-1 Biodiversity 06| Resource efficiency 07| Public Health and well-being > 07.-3 Acoustics	-Help filter air pollutants, capture dust - Provide a habitat for birds and insects - Reduce buildings heat loss - Noise/Acoustic buffer
Possible negative effects	07| Public Health and well-being	-Presence of undesired insects or allergenic plants - Possible damages on the structure or the envelop of the building.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: a building, a façade, a wall.
Impacted scales	The impacted scales are in most cases limited to the building plot or the close neighbourhood. Nevertheless, often, the impacted scale is much larger. The aesthetic of that kind of intervention can contribute to the brand image of a company (a hotel, a headquarter, etc.).
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	2-4 years => depending on the growth of plants and size of structure It takes a bit longer than other types of vertical green structures to cover the top of the surface, because plants start from the soil level.
Life time	It depends on plant species: - More than 30 years for some species, when they are well managed. For example, Wisteria plant. There are also existing successful actions, to obtain the plant while renovation process of a façade by using the construction framing as temporary climbing assistance and add several fixings afterwards.  Fig. Climber green wall before façade renovation and after (MA 22, 2018)

Sustainability and life cycle	Climbing plants and their assistances only require slight interventions to be removed. Moreover, the plants can be composted and the assistance out of steel/wood can be recycled in most cases.
Management aspects (kind of interventions + intensity)	- No or limited irrigation - Pruning (to keep windows and openings clear and to prevent plants from growing onto the roof and guttering) - 1-2 interventions per year - Less or no sensitive to frost in comparison with other types of green walls
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - eventually neighbour - eventually municipalities (monument protection, city scape compatibility, road works, municipal building inspection, ...)
Technical stakeholders & networks	- Landscape architects - Specialized green space management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- Necessity to find an agreement with all the co-owner of a building => importance of the participatory process. - Necessity to inform about the real impacts, to reassure about widespread prejudices (fear to introduce insects in the building, etc.)
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition of the wall • structural context (adjacent buildings) • the wall/facade height • challenges targeted - Chose the support system well adapted to the plant and to the wall materials (concrete, wood, composite panels with insulation, etc.) - Pruning skills for plants such as grapevine, rose climber, etc. in order to get fruits or flowers - Set up the maintenance keeping plants in the right frame (top of the roof, windows, guttering, etc.).
Materials involved	- Climbing plants - Topsoil or substrate - For self-climbing plants, no further material is required just a suitable sub-construction (sandy, poisonous, plastic, glass and fresh concrete plasters are not suitable for self-clinging plants) - For climbers that need a growing support, specific assistances have to be installed along the wall: wires, steel mesh, threads, etc. (cf. Some examples below) - If necessary, fixing for the plant on assistance - Perhaps nutrients

		
Use of wood © Green4Cities	Use of metal structure © MA22	Use of steel mesh © Green4Cities

II.5 Legal aspects related

To install plants on a wall or a façade imply to have the agreement of the owner and eventually a third party if the façade or the wall is not in own property. This can be done in the form of a declaration of consent. Partially, depending on national conditions, in some cases by the use of a climbing assistance and/or the use of public property a building permit and others can be needed.

II.6 Funding Economical aspects

Range of cost	Investment: 10-120 €/m² Maintenance: 1-15 €/m² € (MA 22 2018, FLL 2014) Cheapest solution regarding investment and maintenance for green walls.
Origin of the funds (public, private, public-private, other)	- Depending of the owner of the wall/façade. - Depending on the particular conditions, more and more cities offer a funding for wall greenery by fulfilling basic criteria's.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with solar panels

Linking with solar expositions, and uses, walls can be partly covered by plants and partly by photovoltaic panels.

- Combination with bio-materials

This NBS can also be applied on wall using biomaterials.

Combination of a green façade and photovoltaic panels
© Boutiquehotel Stadthalle Vienna

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Soil quality and volume at the ground - The right plant at the right place (for example growth in relation with the wall/building size)
Limiting factors	- Difficulties of management (for the plants and for the building). The accessibility of the wall is key factor to limit management costs. - Governance and authorizations: building or street owner, maintenance involving co-owners and renter's decisions and payment. It is a project that needs to be shared to do not generate conflicts.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Concrete facade • Double-skin facade • Wooden or metal cladding Compared to typical "grey" facades or structures, greened one have multiple and wide range benefits and touches much more diversity of challenges.
Close NBS	• Planter green wall • Green wall systems The climber green wall is the easiest way of implement of a green wall (technically and financially). But on another hand, planter and green wall systems offer a much higher variety of aesthetic and also environmental effects by much less time.

IV/ References

Note: references presented below are often common with the whole category Vertical structures "Green walls & façades".

IV.1 Scientific and more operational references (presented jointly)

BERNIER Anne-Marie, Montréal Urban Ecology Center, 2011, *Climbing Plants: a refreshing solution*, CEUM, Montréal, 79 pages.

BLANC Patrick, 2008, *The Vertical Garden: From the Nature to the City*, W. W. Norton Company, 192 pages.

COLLINSA Rebecca, SCHAAFSMAB Marije, HUDSONA D Malcom, 2017, *The value of green walls to urban biodiversity*, Land Use Policy, n°64, pages 114-123.

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FRANCIS A. Robert, LORIMER Jamie, 2011, *Urban reconciliation ecology: the potential of livingroofs and walls*, Journal of Environmental Management, Vol.92, I.6, pages 1429-1437.

KINGSBURY Noel, DUNNETT Nigel, 2004, *Planting Green Roofs and Living Walls,* Timber Press, 25 pages.

KÖHLER Manfred, *Green façades – a view back and some visions*, Urban Ecosystems, Vol.11, pages 423–436.

KÖHLER, M. (2012): Handbuch Bauwerksbegrünung

MA 22 (2018): Green wall guideline Vienna. *Municipality department of environmental protection Vienna*

OTTELÉ M. (2011): The Green Building Envelope - Vertical Green

OTTELÉ Marc, PERINI Katia, FRAAIJA A.L.A, HAAS E.M., RAITERI Roberto, 2011, *Comparative life cycle analysis for green façades and living wall systems*, Energy and Buildings, Vol.43 I. 12, pages 3419-3429.

PERINI Katia, ROSASCO Paolo., 2013, *Cost-benefit analysis for green façades and living wallsystems*, Building and Environment, n° 70, pages 110-121.

PRODANOVICA Veljko, HATTB Belinda, MCCARTHYA David, ZHANGB Kefeng, DELETICA Ana, 2017, *Green walls for greywater reuse: Understanding the role of media on pollutant removal*, Ecological Engineering, Vol. 102, pages 625-635.

WEINMASTER Mike, 2009, *Are green walls as Green as they look? An introduction to the various technologies and ecological benefits of green walls*, Green Building, Vol.4, I.4, pages 3-18.

IV.2 Sources used in this factsheet

Green4Cities – www.green4cities.com

MA22, 2018: *Green wall guideline Vienna. Municipality department of environmental protection Vienna.*

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

OTTELÉ M. (2011): The Green Building Envelope - Vertical Green

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I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	This NBS type has no direct connection to the ground but rather an overall substrate body connected to the façade, thus it is often called living wall. There are existing different systems and kinds on the market, but basically it is differentiated in the form and between modular and overall system. A wide range of shrubs, herbs or grasses are typically used to generate a green coverage. An automatic irrigation system and nutrient supply is basically needed due to the extreme conditions of limited substrate body.

Different variants existing

Two main types can be identified, which both further split up between modular and overall system:

=> Position of Plant 90°

This subtype is characterized by the use of plants in the position of 90°. A wide range of shrubs, herbs and grasses can be used by adequate substrate body and irrigation.

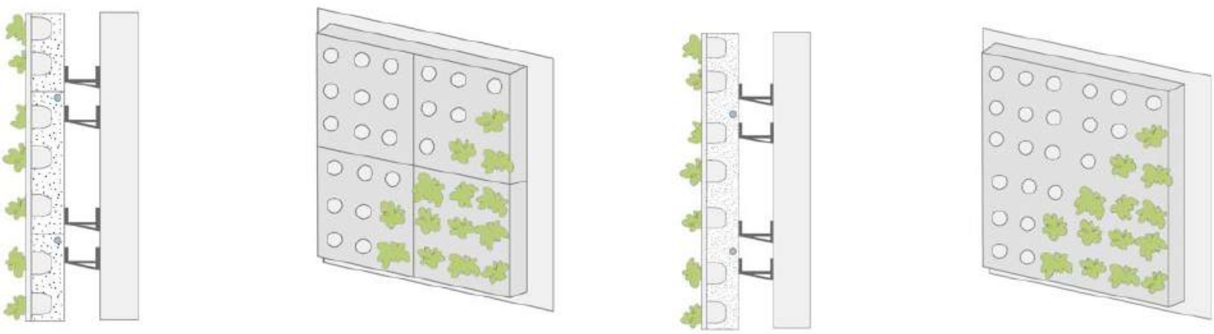

Fig. Position of Plant 90° (left modular system, right overall system) (MA 22, 2018)

Green wall system
© Optigrün

Green wall system
© 90degreen

Green wall system
© 90degreen

=> Position of Plant <90°

These subtype is characterized by the position of the plant lower than 90°. Again it is differentiated between modular and overall system. Typically, a wide range of shrubs, herbs and grasses are used with an adequate substrate body and irrigation.

There are existing different system solutions on the market with different materials. Thereunder also hydroponic systems, which do not use any substrate.

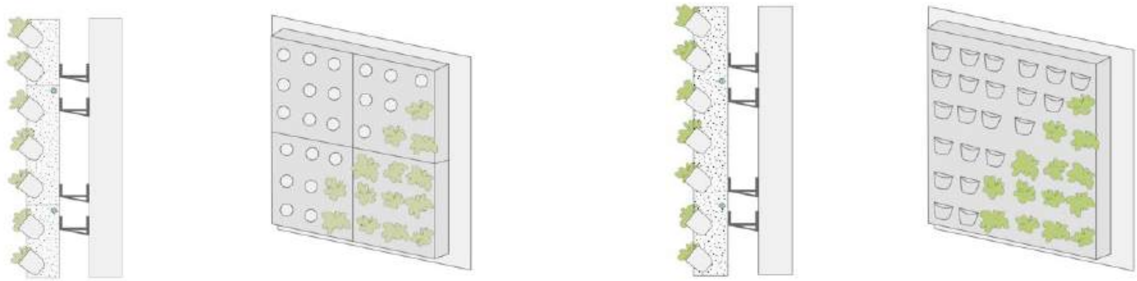

Fig. Position of Plant <90° (left modular system, right overall system) (MA 22, 2018)

Green wall system
© Vertical Magic Garden

Green wall system
© Vertical Magic Garden

Green wall system
© Vertiko

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 07| Public Health and well-being > 07.-2 Quality of life	- Shade building, reduce the heating of walls - Do not contribute to warm air and degrade comfort. Cool surface - Comfort/Aesthetic value - Contact with nature - Support for education
Co-benefits and challenges foreseen	03| Air quality issues 04| Biodiversity and Urban Space > 04-1 Biodiversity 06| Resource efficiency 07| Public Health and well-being > 07.-3 Acoustics	-Help filter air pollutants, capture dust - Provide a habitat for birds and insects - Reduce buildings heat loss - Noise/Acoustic buffer
Possible negative effects	07| Public Health and well-being	- Presence of undesired insects or allergenic plants

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: a building, a façade, a wall.
Impacted scales	The impacted scales are in most cases limited to the building plot or the close neighbourhood. But often, the impacted scale is much larger. The aesthetic of that kind of intervention can contribute to the brand image of a company (an hotel, a headquarter, etc.).
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Nearly immediately to 1 or 2 years => depending on functionality of the chosen system
Life time	It depends on the functionality of the chosen system and used materials: - up to 50 years In moderate climate several systems need regular replanting because of plant losses.
Sustainability and life cycle	Depending on the functionality of the chosen system. Systems are often made out of PVC and/or metal. In general, very intense resource input (irrigation, often replanting, high maintenance). By renovation it has to be totally rebuild.
Management aspects (kind of interventions + intensity)	- Automatic irrigation + maintenance - Pruning, replanting and maintenance (technical parts) - 1-4 interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Eventually neighbour - Eventually municipalities (monument protection, city scape compatibility, road works, municipal building inspection, ...)
Technical stakeholders & networks	- Architect - Structural engineering - Landscape architects - Specialized green space management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- Necessity to find an agreement with all the co-owner of a building => importance of the participatory process. - Necessity to inform about the real impacts, to reassure about widespread prejudices (fear to introduce insects in the building, etc.)
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition of the wall • wind • structural context (adjacent buildings) • substrate depth/body • position/orientation of plant • challenges targeted - Chose a functional green wall system with adequate substrate body - Adequate (automatic) irrigation - Pruning skills - Set up the maintenance (technical installations like irrigation, ...).

Materials involved	- Plants: shrubs, herbs, grasses - Green wall system - Substrate (can e.g. contain out of recycled brick) or body (e.g hydroponic geotextile system) - Automatic Irrigation

		
Dripping hole irrigation © Green4Cities	Use of substrate © Green4Cities	Fleece/geotextile © Green4Cities

II.5 Legal aspects related

To install plants on a wall or a façade imply to have the agreement of the owner and eventually a third party if the façade or the wall is not in own property. This can be done in the form of a declaration of consent. Depending on national conditions, the implementation of green wall system can assume a building permit or any other permit. In some countries also the fire safety topic is a big issue and have to be prevented through actions and attested for the system.

II.6 Funding Economical aspects

Range of cost	Investment: 1000-1200 €/m² and more Maintenance: 10-70 €/m² and more (MA 22 2018, FLL 2014) Regarding investment and maintenance this type of green wall is most resource-intense.
Origin of the funds (public, private, public-private, other)	- Depending of the owner of the wall/façade. - Depending on the particular conditions, more and more cities offer a funding for wall greenery by fulfilling basic criteria's.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with bio-materials

This NBS can also be applied on wall using biomaterials.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	- Technical functionality of the green wall system - Adequate substrate body - Adequate irrigation - The right plant choice
Limiting factors	- Difficulties of management (for the plants and for the building). The accessibility of the wall is key factor to limit management costs. - Governance and authorizations: building or street owner, maintenance involving co-owners and renter's decisions and payment. It is a project that needs to be shared to do not generate conflicts.

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Concrete facade • Double-skin facade • Wooden or metal cladding • Glass facade Compared to typical "grey" facades, greened one have multiple and wide range benefits and touches much more diversity of challenges. And e.g. glass facades have to be cleaned as well.
Close NBS	• Climber green wall • Planter green wall The Green wall system is the most technical and expensive solution to implement green on a wall. But it offers the highest variety of aesthetic and also environmental effects by lowest time.

IV/ References

Nota: references presented below are often common with the whole category Vertical structures "Green walls & façades".

IV.1 Scientific and more operational references (presented jointly)

BERNIER Anne-Marie, Montréal Urban Ecology Center, 2011, *Climbing Plants: a refreshing solution*, CEUM, Montréal, 79 pages.

BLANC Patrick, 2008, *The Vertical Garden: From the Nature to the City*, W. W. Norton Company, 192 pages.

COLLINSA Rebecca, SCHAAFSMAB Marije, HUDSONA D Malcom, 2017, *The value of green walls to urban biodiversity*, Land Use Policy, n°64, pages 114-123.

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FRANCIS A. Robert, LORIMER Jamie, 2011, *Urban reconciliation ecology: the potential of livingroofs and walls*, Journal of Environmental Management, Vol.92, I.6, pages 1429-1437.

KINGSBURY Noel, DUNNETT Nigel, 2004, *Planting Green Roofs and Living Walls,* Timber Press, 25 pages.

KÖHLER Manfred, *Green façades – a view back and some visions*, Urban Ecosystems, Vol.11, pages 423–436.

KÖHLER, M. (2012): Handbuch Bauwerksbegrünung

MA 22 (2018): Green wall guideline Vienna. *Municipality department of environmental protection Vienna*

OTTELÉ M. (2011): The Green Building Envelope - Vertical Green

OTTELÉ Marc, PERINI Katia, FRAAIJA A.L.A, HAAS E.M., RAITERI Roberto, 2011, *Comparative life cycle analysis for green façades and living wall systems*, Energy and Buildings, Vol.43 I. 12, pages 3419-3429.

PERINI Katia, ROSASCO Paolo., 2013, *Cost-benefit analysis for green façades and living wallsystems*, Building and Environment, n° 70, pages 110-121.

PRODANOVICA Veljko, HATTB Belinda, MCCARTHYA David, ZHANGB Kefeng, DELETICA Ana, 2017, *Green walls for greywater reuse: Understanding the role of media on pollutant removal*, Ecological Engineering, Vol. 102, pages 625-635.

WEINMASTER Mike, 2009, *Are green walls as Green as they look? An introduction to the various technologies and ecological benefits of green walls*, Green Building, Vol.4, I.4, pages 3-18.

IV.2 Sources used in this factsheet

Green4Cities – www.green4cities.com

MA22, 2018: *Green wall guideline Vienna. Municipality department of environmental protection Vienna.*

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

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V/ Author(s)

Name	Institution / company	Writer/ reviewer
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Johannes Anschober	GreenCitites	Writer
Philippe Bodénan	Cerema	Writer
Olivier Damas	Plante&Cité	Writer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition	This NBS type is about the use of planters or pots with artificial substrate. They can be on the ground or directly on the building or balconies. They can be used nearly with every kind of plants, e.g. climbing plants, trees and/or shrubs.

Different variants existing

Two main types can be identified, which further split up depending on the botanical properties:

=> Spotty planter

This subtype deals with spotty solutions by using single planters, which can be located on the ground, façade or balcony. Nearly the whole range of plants can be used by adequate substrate volume and irrigation.

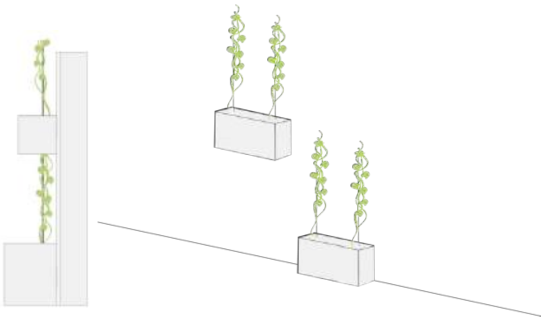
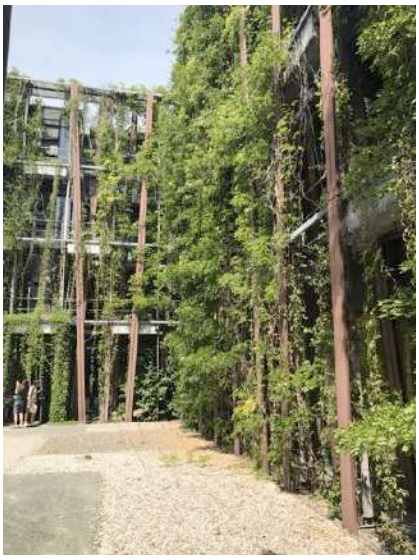


Fig. Spotty planter solution (MA 22, 2018)



Berlin Adlershof – mixture of climbers on ground and in planters
© Green4Cities

Bosco Verticale
© Green4Cities

District department Margarethen Vienna
© Green4Cities

=> Linear planter

These variant is characterized by the solution of linear systems (planter, pots, ...) with differences in the vertical distance. It is further structured into <=50 cm distance between the single greening elements and >50cm distance. Typically, plants can range from climbing plants to shrubs. Compared to the spotty solution, the linear ones sometimes have less substrate volume and access, thus as much more an automatic irrigation is needed to supply plants with water.

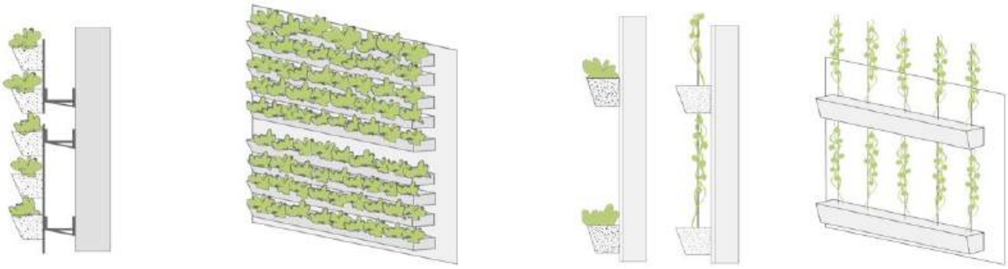


Fig. Linear system solutions (left <= 50 cm distance; right > 50 cm distance) (MA 22, 2018)

B.R.O.T. Geblergasse Vienna
© Green4Cities

BOKU Vienna
© Green4Cities

MA 48 Vienna
© Green4Cities

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 07| Public Health and well-being > 07.-2 Quality of life	- Shade building, reduce the heating of walls - Do not contribute to warm air and degrade comfort. Cool surface - Comfort/Aesthetic value - Contact with nature - Support for education
Co-benefits and challenges foreseen	03| Air quality issues 04| Biodiversity and Urban Space > 04-1 Biodiversity 06| Resource efficiency 07| Public Health and well-being > 07.-3 Acoustics	-Help filter air pollutants, capture dust - Provide a habitat for birds and insects - Reduce buildings heat loss - Noise/Acoustic buffer
Possible negative effects	07| Public Health and well-being	Presence of undesired insects or allergenic plants

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	The object: a building, a façade, a wall.
Impacted scales	The impacted scales are in most cases limited to the building plot or the close neighbourhood. But often, the impacted scale is much larger. The aesthetic of that kind of intervention can contribute to the brand image of a company (an hotel, a headquarter, etc.).
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1-4 years => depending on the chosen system, growth of plants and size of structure They can have the similar time frame like ground-based climbers, but it is also possible to have the full effect faster, by choosing the appropriate system and/or plant sizes.
Life time	It depends on plant species and materials: - More than 30 years for some species, when they are well managed. For example, Wisteria plant.
Sustainability and life cycle	Depending on the complexity of the chosen system and construction. Can be similar like by climbing plants but also very intense to rebuild it.
Management aspects (kind of interventions + intensity)	- Automatic irrigation + nutrient supply + technical maintenance - Pruning (to keep windows and openings clear and to prevent plants from growing onto the roof and guttering) - 1-2 interventions per year
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - Tenants - Eventually neighbour - Eventually municipalities (monument protection, city scape compatibility, road works, municipal building inspection, ...)
Technical stakeholders & networks	- Architect - Structural engineer - Landscape architects - Specialized green space management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	- Necessity to find an agreement with all the co-owners of a building => importance of the participatory process. - Necessity to inform about the real impacts, to reassure about widespread prejudices (fear to introduce insects in the building, etc.)
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition of the wall • structural context (adjacent buildings) • expected planting area (wall/facade height – differences between planters) • substrate depth • challenges targeted - Chose a technical proper planter - Adequate substrate depth and volume.

	- Adequate (automatic) irrigation and nutrients - Chose the support system well adapted to the plant and to the wall materials (concrete, wood, composite panels with insulation, etc.) - Pruning skills for plants such as grapevine, rose climber, etc. in order to get fruits or flowers - Set up the maintenance keeping plants in the right frame (top of the roof, windows, guttering, etc.) and check the technical installations (irrigation, ...).
Materials involved	- Climbing plants - Planter - Substrate (can e.g. contain out of recycled brick) - Irrigation - For climbers that need a growing support, specific assistances have to be installed along the wall: wires, steel mesh, threads, etc. (cf. Some examples below) - If necessary, fixing for the plant on assistance

		
Planter out of metal © Green4Cities	Use of substrate © Green4Cities	Sensor-based automatic irrigation © Green4Cities

II.5 Legal aspects related

To install plants on a wall or a façade imply to have the agreement of the owner and eventually a third party if the façade or the wall is not in own property. This can be done in the form of a declaration of consent. Depending on national conditions, the implementation of planter green walls can assume a building permit or any other permit.

II.6 Funding Economical aspects

Range of cost	Investment: 400-1000 €/m² and more Maintenance: 10-25 €/m² and more (MA 22 2018, FLL 2014) Regarding investment and maintenance this type of green wall is in the middle.
Origin of the funds (public, private, public-private, other)	- Depending of the owner of the wall/façade. - Depending on the particular conditions, more and more cities offer a funding for wall greenery by fulfilling basic criteria's.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with bio-materials

This NBS can also be applied on wall using biomaterials

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Technical functionality of the planter - Substrate quality and volume - Adequate irrigation and nutrients - The right plant at the right place (for example growth in relation with the wall/building size/differences between planters)
Limiting factors	- Difficulties of management (for the plants and for the building). The accessibility of the wall is key factor to limit management costs. - Governance and authorizations: building or street owner, maintenance involving co-owners and renter's decisions and payment. It is a project that needs to be shared to do not generate conflicts.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	• Concrete facade • Double-skin facade • Wooden or metal cladding • Glass facade Compared to typical "grey" facades, greened one have multiple and wide range benefits and touches much more diversity of challenges.
Close NBS	• Climber green wall • Green wall systems The planter green wall is another efficient way of implement of a green wall (technically and financially). Compared to climbers, they offer a much higher variety of aesthetic and also environmental effects by much less time.

IV/ References

Nota: references presented below are often common with the whole category Vertical structures "Green walls & façades".

IV.1 Scientific and more operational references (presented jointly)

BERNIER Anne-Marie, Montréal Urban Ecology Center, 2011, *Climbing Plants: a refreshing solution*, CEUM, Montréal, 79 pages.

BLANC Patrick, 2008, *The Vertical Garden: From the Nature to the City*, W. W. Norton Company, 192 pages.

COLLINSA Rebecca, SCHAAFSMAB Marije, HUDSONA D Malcom, 2017, *The value of green walls to urban biodiversity*, Land Use Policy, n°64, pages 114-123.

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FRANCIS A. Robert, LORIMER Jamie, 2011, *Urban reconciliation ecology: the potential of livingroofs and walls*, Journal of Environmental Management, Vol.92, I.6, pages 1429-1437.

KINGSBURY Noel, DUNNETT Nigel, 2004, *Planting Green Roofs and Living Walls,* Timber Press, 25 pages.

KÖHLER Manfred, *Green façades – a view back and some visions*, Urban Ecosystems, Vol.11, pages 423–436.

KÖHLER, M. (2012): Handbuch Bauwerksbegrünung

MA 22 (2018): Green wall guideline Vienna. *Municipality department of environmental protection Vienna*

OTTELÉ M. (2011): The Green Building Envelope - Vertical Green

OTTELÉ Marc, PERINI Katia, FRAAIJA A.L.A, HAAS E.M., RAITERI Roberto, 2011, *Comparative life cycle* *analysis for green façades and living wall systems*, Energy and Buildings, Vol.43 I. 12, pages 3419-3429.

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IV.2 Sources used in this factsheet

Green4Cities – www.green4cities.com

MA22, 2018: *Green wall guideline Vienna. Municipality department of environmental protection Vienna.*

FLL (2014): Leitfaden Gebäude, Bebrünung und Energie: Potenziale und Wechselwirkungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

FLL (2018): Fassadenbegrünungsrichtlinien – Richtlinien für die Planung, Bau und Instandhaltung von Fassadenbegrünungen. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau.

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Marjorie Musy	Cerema	Reviewer
Olivier Damas	Plante&Cité	Writer

I/ General description and characterization of the NBS type

I.1 Definition and different variants existing

Definition

The use of garden structures in combination with plants has a long tradition and goes back to the ancient times to the gardens of Mesopotamia, Egypt, Persia and China (app. 2000-500 BC). Over time a variety of terminology has formed and a clear definition of the different structures is not that easy all time. Nevertheless, it’s always about a kind of built structure which uses pillars, beams and lattices in different materials and compositions to create a growing assistance for vegetation (Hansen 2010).

Different variants existing

Three kinds can be identified, depending on the utilisation form (Hansen 2010):

=> Arbour

The origins of arbours are in Egyptian gardens, further also used by the Romans and later throughout Europe. It’s basically an enclosed or recessed area which is shaded by plants. A modern one’s often have a latticework on a frame, vegetated by climbing plants. A sheltering bench under the construction is a distinguishing characteristic for a real arbour.

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=> Pergola

From ancient Egyptian gardens also Pergolas origin which were further introduced to Italy. A Pergola is typical a linear structure containing pillars and crossbeams as well as a latticework common in combination with climbing plants, to shade a walkway.

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=> Trellis

Trellises are coming originally from 17th centuries Dutch gardens and got later on popular in US and Germany. It's usually a free-standing and small wooden or metallic structure as support for plants by a framework of crossbars. Further it can also be a flat structure attached at a wall, between beams or for use in orchards - typically to grow espalier fruits.

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I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate adaptation 07| Public Health and well-being > 07-2 Quality of life	- Shading area - Contact with nature - Aesthetic value - Support for education
Co-benefits and challenges foreseen	03| Air quality issues > 03-2 Air quality locally 04| Green space management including biodiversity >04-1 Biodiversity 06| Resource efficiency > 06-1 Food, energy and water	-Help filter air pollutants - Provide a habitat for birds and insects - Food production
Possible negative effects	07| Public Health and well-being	- Presence of undesired insects

II/ More detailed information on the NBS type

II.1 Description and implication at different spatial scales

Scale at which the NBS is implemented	Object: in a park, open space, garden, courtyard
Impacted scales	The impacted scale is in most cases limited to the object level.

II.2 Temporal perspective (including management issues)

Expected time for the NBS to become fully effective after its implementation	1-4 years => depending to the growth of plants and size of structure
Life time	It depends on plant species: - More than 30 years and more for some species, when they are well managed. For example, Wisteria plant. - Some plants need to be replaced after 4-6 years. Indeed, after many years, they develop senescence aspects. Oldest stems become lignified and do not carry leaves any more.
Sustainability and life cycle	Depending on the structure and the used materials.
Management	- No or limited irrigation

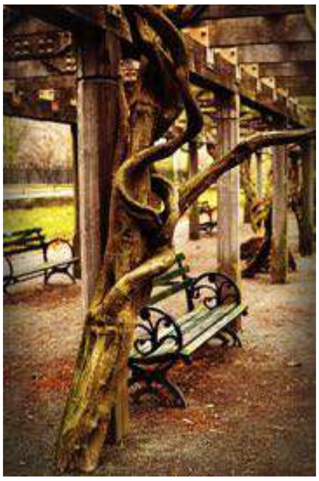
aspects (kind of interventions + intensity)	- Pruning (to form plant to structure) - Harvesting, fruit picking - 1 intervention per year

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Depending on location - Owners, co-owners (in case of a joint ownership property) - Tenants - eventually neighbour or municipality
Technical stakeholders & networks	- Private person - Landscape architects - Specialized green spaces management firms, horticulturist and gardeners. - The technical stakeholders network for this kind of NBS is well identified.
Social aspects	-May be necessary to find an agreement with all the co-owner of a garden => importance of the participatory process.

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Selection of plant adapted to: • the local climate • the exposition of the structure • the structure size/height • challenges targeted - Chose the support system (climbing aid) well adapted to the plant - Pruning skills for plants such as grapevine, rose climber, etc. in order to get fruits or flowers - Set up the maintenance keeping plants in the right frame.
Materials involved	- Climbing plants - Climbing Structure - Bindings to fix the plant on its support



Use of wood
© Green4Cities

Use of metal
© Green4Cities

Use of material combinations
© Green4Cities

II.5 Legal aspects related

Depending on the location and stakeholder situation.

II.6 Funding Economical aspects

Range of cost	Investment: 30-120€ / m²
Origin of the funds (public, private, public-private, other)	nA

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Combination with photovoltaic panels

Pergolas can be partly covered by plants and partly by perforated photovoltaic panels which allows thus to combine shading, urban gardening and electricity production easily by just one installation and also possible on roofs. The experienced temperature under the construction is 3-5 °C lower than in the direct sun (Biosolarroof 2015, BOKU nA)

olar roof garden pergola © Green4Cities

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	- Soil quality and appropriate climbing assistance for the right plant
Limiting factors	nA

III.2 Comparison with alternative solutions

Grey or conventional solutions counterpart	• Shading structures The shading effect can be produced by other sun protection system, but the use of plants further gains an air cooling effect and in combination with the structural elements a very aesthetic effect.
Close NBS	• Climber Green wall • Planter Green wall Plant selection and needs are similar.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

BIOSOLARROOF (2015): Solar Roof Garden. Online: http://biosolarroof.eu/solar-roof-garden/

HANSEN Gail (2010): Arbor, Trellis, or Pergola – What's in your garden? A Mini-Dictionary of Garden Structures and Plant Forms. University of Florida IFAS Extension. Online: http://edis.ifas.ufl.edu/ep432

ROBINSON Nick (2004): The Planting Design Handbook. Taylor & Francis. Second Edition. New York.

BOKU - UNIVERSITY OF NATURAL RESOURCES AND LIFE SCIENCE VIENNA: (nA): Photovoltaic Greenroof Systems. Vienna. Online: https://www.baunat.boku.ac.at/en/iblb/forschung/schwerp/vegetationstechnik/strom-erzeugenden-dachgarten-der-zukunft/

IV.2 Sources used in this factsheet

Green4Cities – www.green4cities.com

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Johannes Anschober	Green4Cities	Writer

Strategies & Actions

- **Urban (green) spaces management**
- **Waste management**
- **Protection and conservation strategies**
- **Urban planning strategies**
- **Monitoring**

➢ Urban (green) spaces management

➢ Direct human interventions

> SUSTAINABLE USE OF FERTILISERS

> INTEGRATED PEST MANAGEMENT

> INTEGRATED WEED MANAGEMENT

> INTEGRATED AND ECOLOGICAL MANAGEMENT: SPATIAL ASPECTS

> INTEGRATED AND ECOLOGICAL MANAGEMENT : TIME AND FREQUENCY ASPECTS

> CREATE AND PRESERVE HABITATS AND SHELTERS FOR BIODIVERSITY

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Sustainable use of fertilisers (SUF) is a nature-based strategy that combines a limited use of mineral fertiliser, the promoted use of organic fertilisers or/and biostimulants, the consideration of soil properties and soil biology. The decision on quantities of inputs used is taken in a balanced and integrated way. Sometimes the use of fertilisers may not be necessary. SUF aims at minimizing the economical and environmental costs of fertilisation practices such as use of fossil energies, water eutrophication, soil contamination, loss of biodiversity, sensitivity to pests. Fertiliser means "material, the main function of which is to provide nutrients for plants." [Regulation (EC) 2003/2003]. Soil enrichment products are not considered as fertilisers.

SUF is based on (1) the careful and wise consideration of all factors involved in plants nutrition, and on (2) the level of services expected from the use of plants (ex. crop production, recreational area, area devoted to biodiversity concerns).
Here are some of its possible factors and principles.

⇨ **Limiting the mineral fertilisers and fostering the organic fertilisers**

Mineral nitrogen production implies the use of important fossil energy quantity. Other mineral elements are non-renewable sources (mining materials) while organic matters are renewable and recycled resources.
Transport may induce very different levels of externalities independent from the mineral or organic origin.

⇨ **Taking into account and improve the soil properties and its ecological functioning**

Beside any mineral and organic fertilisers may affect the water quality downstream the water basin if its use is excessive. Soil physicochemical analysis and soil appreciation is the key to decide the proper amounts and type of fertilisers to implement. Soil ecological functioning appreciation is a complementary key to improve the fertilisation management.
Many practices allow to improve the soil properties and to lower the use of fertilisers. All these are NBS and are based on maintaining or increasing the organic matter quantity in the soil. For example: organic soil enrichment products, organic mulching, green manure crops, green wastes grinding.

⇨ **Use of biostimulants**

Biostimulants stimulate and improve the nutritive conditions of plants. They are micro-organisms (fungi, such as mycorrhizae, bacteria), plant extracts (algae extracts, amino acids), mineral extracts (ex. humic acids).

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues >01.1 Climate mitigation 05| Urban regeneration and Soil >05.1 Soil management 06| Resource efficiency >06.1 Food, energy and water >06.3 Waste >06.4 Recycling 11| Green economy >11.1 Circular economy >11.3 Direct economic value of NBS	- Lower the use of fossil energy and its related climate consequences - Improve soil properties and consideration - Based on organic matter recycling, living organisms and ecological functioning, it also reduces waste.

Co-benefits and challenges foreseen	02| Urban water management and quality >02.1 Urban water management 04| Urban space and Biodiversity >04.1 Biodiversity	- Limit eutrophication in water and soils - Improve soil biodiversity
Possible negative effects	05| Urban regeneration and Soil 05.1 Soil management 06| Resource efficiency 06.1 Food, energy and water 11| Green economy 11.3 Direct economic value of NBS	- For agricultural purposes, if fertilisation inputs are lower than the crop needs then it affects the production yield. - Over-fertilisation induces pollution (excess of nutrients) downstream the site of fertilisation, and biodiversity loss - Both organic and chemical fertilisers quality has to be checked. Their content in trace elements may induce soil and crop pollution.

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Scale is the plot or the garden.
Impacted scales	The main scale to consider is the plot (fertilisation effect). In terms of avoided pollution potential, the scale is the water basin.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	The effect is immediate since the principle is to avoid externalities from fertilisation practices.
Life time	As for the fertiliser effect, more or less one year depending on the fertiliser. As for a fertilisation plan, its duration is from 3 or 5 years if very sophisticated, to 5-10 years if more simple.
Sustainability and life cycle	The more the fertiliser is based on organic matters, the more it is sustainable. Mineral nitrogen production implies the use of fossil energy (1 ton of nitrogen = 1,5 ton equivalent petroleum). Mineral phosphorous and potassium come from mines that are non-renewable sources. Organic matters are renewable and recycled resources. Transport may induce very different levels of externalities independent from the mineral or organic origin. Both mineral and organic fertilisers may affect the water quality downstream the water basin, although the evolution speed is generally lower for organic fertilisers.
Management aspects (kind of interventions + intensity)	- Regular soil monitoring and assessment (high) - Define aims and level of services expected (high) - Plan a strategy and actions related to these aims (high) - Communication and training courses towards operational stakeholders (intermediate to high)

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- The operator in charge of the maintenance (from the gardener to the director) for green spaces purposes - The crop producer for agricultural purposes
Technical stakeholders & networks	Same stakeholders
Social aspects	The evolution in practices and way of thinking implies education, communication, and a technical governance in order to plan and share the objectives and the technical practices.
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	Knowledge on organic matter and organic fertiliser (composition, evolution phenomenon, mineralisation speed).
Materials involved	No specificity for materials in comparison with conventional practices. The use of wood grinding machine may be more frequent since the use of organic matter and compost is increased.

II.5 Legal aspects related

See every specific national rules.
For EC rules, the ‘EC fertilisers’ Regulation (EC) 2003/2003 relate the rules for the mineral fertilisers and mineral alkaline soil adjustment products. An update is in progress with the aim to extend the range to any fertilisers and soil enrichment products.

II.6 Funding Economical aspects	
Range of cost	The range of costs depends on the quality of the fertiliser and the quantity ordered. An organic fertiliser costs generally between 1 and 4 euros per kg (case of 25 kg bag) Individual nutrients costs are (case of orders in tons): - Nitrogen ~ 3 €/kg - Phosphorous ~ 1 €/kg - Potassium ~1.5 €/kg - Neutralising value 0.15 €/kg. Soil enrichment products are cheaper. For example, compost 40 euros per ton; manure 100 euros per ton, concentrated products from 250 to 500 euros per ton.
Origin of the funds (public, private, public-private, other)	The funds come from the operator of the action, that is, the final user (private or public). No or rare grants for this in urban context (different from agricultural context).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

- Use of compost and organic mulch. The compost may substitute a partial or the entire quantity of fertiliser needs.
- Soil and global biodiversity enhancement, since it ensures life and nutrients cycles, and biostimulation (mycorhizes for example).

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Soil assessment and appreciation - Soil knowledge, including ecology and biology - Answer the question "Is a fertiliser necessary for my purpose and level of services expected?" and then adapt/plan the practices
Limiting factors	- The use of organic fertiliser may be more difficult since the availability of nutrients for plants is not immediate in comparison with mineral fertilisers - Consent of stakeholders to change the practices
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Mineral fertilisers use
Close NBS	- composting - mulching - bioindicators

IV/ References

IV.1 Scientific and more operational references (presented jointly)
European Biostimulants Industry Council (EBIC). www.biostimulants.eu [consulted in April 2018]
IV.2 Sources used in this factsheet
EUROPEAN COMMISSION, 2003. Regulation (EC) 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilisers. LARGANT L., 2017. *Raisonner la fertilisation* (pp 49-51), in *Aménager et gérer avec frugalité : préserver les ressources en faisant mieux avec moins*, Plante & Cité, Angers, 68 p. SOLTNER D., 2015. *Les bases de la production végétale*, Soltner, Bressuire, 3 volumes (Collection Sciences et techniques agricoles, 3 volumes: le sol, le climat, la plante).

V/ Author(s)

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Integrated pest management (IPM) is an ecosystem-based strategy that combines the available pest control methods (genetic, physical, biotechnological, biological, semio-chemical, chemical) in a balanced and optimised way. Although IPM may be understood at a larger scale (animal pests and weeds) the scope of this NBS is limited to animal pests (mostly insects). The NBS Integrated weed management (IWM) for weed concerns can be consulted. IPM aims at managing but not suppressing plant pathogens, organisms that damage or interfere with green spaces plants (including but not limited to exotic invasive species). IPM keeps pest population (pest pressure) under a socially, sanitary and economically acceptable threshold. It minimizes the use of pesticides and enhances green space ecological functioning.

IPM is based on careful consideration of all pest control methods available and is always a wise and appropriate combination of techniques that may go as far as a no-pesticide strategy.
Choice is made in accordance with the pest (and the available techniques against it), the level of damage (and the estimated acceptance threshold), the level of will about pesticide reduction and eventually money and time. Here are some of its possible components.

- **Biological control:** involves natural-based products (plants, animals, mineral products, microorganisms). It may conserve (management of beneficial flora, preservation or attraction of beneficial fauna, avoiding the use of pesticides, etc.), increase (introduction of a large amount of beneficial organisms, once or repeatedly) or acclimatise (in the case of exotic invasive pest, introduction of a regulatory organism from the same area of origin as the pest, often a natural predator).

Great Tit nest box (insectivorous bird) © Maxime Guérin, Plante & Cité

Stratified vegetation of a Mediterranean hedge in green space able to attract many beneficial organisms © Girod G., CIME

Lady Bug feeding on scale insects © Pollinator

⇨ **Genetic control:** favours diseases-resistant or -tolerant plants (different species, variety, cultivar)

The red Horse Chestnut is or more resistant species that the usual with one © Rüdiger Wölk

⇨ **Physical control:** often a net sheltering trees or shrubs from egg-laying pests

A net protects this palm against the palm weevil © Maxime Guérin, Plante & Cité

⇨ **Semiochemical** control: use of a synthetic homologue of the pest sex pheromone to disrupt mating.

⇨ **Chemical control** (conventional techniques): pesticides application. This should be regarded as a last resort technique.

⇨ **Alternative techniques**: for example, traps to collect and destroy pests

Pheromone trap against the Pine Processionary Moth © Maxime Guériun, Plante & Cité

⇨ **Prophylaxis**: as a long-term management technique, this set of methods should be a green space conception and management strategy from the beginning. Pest management is self-induced and doesn't go as far as a conspicuous pest invasion.

It is nonetheless possible to implement this choice at any time, and even during or after a pest invasion. The added value will last and increase over time. See the close NBSs to know more.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity 07| Public Health and well-being > 07-3 Health	- maintaining or improving quality of existing green spaces - less chemical products released in the environment
Co-benefits and challenges foreseen	01| Climate > 01-1 Climate mitigation 05| Soil management > 05-1 Soil management and quality 06| Resource efficiency > 06-1 Food, energy, water > 06-2 Raw material	- reduction of synthetic petrol-based pest control products saves oil resources and greenhouse gaz emissions - maintaining and improving soil biodiversity - reduction of synthetic petrol-based pest control products saves energy and oil resources,
Possible negative effects	07| Public Health and well-being 08| Environmental justice	- acceptability and tolerance threshold - risk of pest introduction -(weed) acceptability of wild flowers (considered as dirty, shabby) - more insects, more allergenic plants

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Green space
Impacted scales	Green space Ecological corridors (green strips, etc.) Other surrounding green spaces

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Response is the matter of a weeks in most cases if IPM is implemented at the right time.
Life time	IPM is a long-term process: it usually involves at least another step (at the next stage of insect life cycle for example) to ensure success over time.
Sustainability and life cycle	IPM is designed as a sustainable approach. Monitoring of pests and plant health as well as follow up of material and devices and yearly replacement of some of them is required, but the overall implementation is stable in time with growing efficiency.
Management aspects (kind of interventions + intensity)	- Monitoring and follow up - Plant-health monitoring at a larger scale (region, country), in addition to a knowledge of previous pest proliferation periods of the year, allow to anticipate the right action at the right time (for example, buy chrysops larvae just before the known period of aphids proliferation) - Communication towards public

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality green spaces department - Biological pest control companies - Ecological engineering and consultancy companies
Technical stakeholders & networks	- Specialised green spaces management firms, horticulturists and gardeners, often city intern departments - Ecological engineering and consultancy companies - Communication department: social acceptance is at the heart of such projects
Social aspects	Green spaces users need to understand why they are seeing traps, boxes etc. in a place they enjoy. A higher threshold acceptance of minor pest damage is also observed whenever citizen and inhabitants are kept informed. This may be carried out through on-site panels and notice board, and through municipality web-site.

II.4 Design / techniques/ strategy	

Knowledge and know-how involved	- Know the pest: some strategies involve precise knowledge of the pest (species and sometimes the insect phase at concern). There are several techniques and tools to achieve this knowledge by observations on field (for larval and adult phase) and through various trapping devices (for adult – mobile- phase). Observation and monitoring also allows to assess the presence of useful fauna, beneficial organisms which feed on or parasite pests.
	- Decide, assess and weight up:
	  o the level of damage which is socially acceptable
	  o the available budget
	  o internal skills, number of employee, amount of time that is possible to affect to the task
	  o features of the site: type of green space (type of use), size, type of vegetation, users' frequentation, existing favourable spots or features (for example existing shelters for beneficial organisms, number of pest-targeted trees, etc.)
	- Browse the professional press for management feedback and existing strategies, ask other municipalities about their practices for the same issue, seek out expert advice (from specialised green spaces management firms, ecological engineering and consultancy companies, academic research labs), look for official guidance: some pests are of national or European concern.
	- Define a strategy, carefully considering all available techniques.
	- Carefully plan your strategy in time and space: where to put the devices for best result, when to implement each step. For example, an accurate technique targeting larvae is irrelevant when adults fly.
	- Start implementation. According to pest targeted and level of infestation, there may be steps to follow all along the year (at least)
	
	For better efficiency, and better sustainability, this NBS should be included in an overall integrated and ecological management plan.

	Plant material Traps, pheromones diffusers, pesticide or microbiological solution sprayer (bought) Living macro-organisms when biological control is involved (bought or attracted by a proper strategy). To maintain long-term population of beneficial organisms on site, nest boxes and other shelters (bought, or internally made), and plants attracting beneficial organisms (sowed or planted, bought or found on site).

II.5 Legal aspects related

- *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council*
- Local (country) regulations
- It is mandatory to file an authorization's application before the introduction of alien beneficial organisms.

II.6 Funding Economical aspects	
Range of cost	From almost free (long-term pest management strategy already in place, keeping pest population under economic and social injury level) to some thousand euros. Working time is often internal (municipality gardeners, etc.). Example: estimation of the pine processionary moth with the following features: a 2 000 m² school green space; planted with 20 pines; one person (internal staff) mans the work; implementation starts in summer (when moth adult stage appears). 0) Continuous management: **let Great tits and other insectivorous birds work on pest populations**: 2 to 8 nest boxes /ha → 4x21 € = **84 €** (if bought) 1) In summer (y1): **adult trap** → 6 pheromone traps devices per hectare + pheromones diffusers, at least 3: 3x62,5 € + 2x16,9 € = **187,5 €** (assuming protection equipment is already available for the team) 2) In autumn (y1): insecticide application on caterpillar -> *Bacillus thurengienis kurstaki* Foray 48 B (bio-insecticide) 3L/ha → 3 bottles (1 L) = 3x65,9 € **197,7 €** 3) In winter (y1): **physical suppression of nests** (branches carrying nests are cut off): **0 €** (internal work, assuming the municipality owns protection equipment and adapted vehicles) 4) In spring (y2): **trap of remaining caterpillars** (is needed): 1 eco-trap per tree =20x35,7 € x 0,75 =**535,5 €** Traps are reusable several years, but diffusers are new every year. Total: **1 004,7 €** tax included. This example was **done in the case of a high constraint level** (school green space), If the green space is open and not specifically frequented by children, **steps 0, 1 and 4 are satisfying (807 €)**. (prices estimated from sail retailers' websites. Estimation source: Plante & Cité)
Origin of the funds (public, private, public-private, other)	Public. Budget to be integrated in green spaces management budget, and/or in biodiversity improvement strategy budget.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

This NBS greatly benefits from inclusion in an overall integrated and ecological management plan (see related NBSs). IPM may be considered as one aspect of an integrated management plan for green spaces.

Eco-trap against the Pine Processionary Moth in an ecologically managed green space © Maxime Guérin

This NBS is also related to habitats and shelters for biodiversity (see related NBS) to better maintain, promote or attract beneficial organisms, whose larvae or adult stage often feed on pests or parasites them.

Maintaining pollen- and nectar-producing plants and vegetation of different type and age helps maintaining on site beneficial organisms © Sarah Meyer, Gondwana

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Early detection of an infestation - Knowledge of the pest - Careful examination of all methods available, their advantages and disadvantages, their manageability (site-dependant, team-dependant, politics-dependant)
Limiting factors	- Possibly features of the site - Design a strategy without seeking for expert skills or other municipalities' feedback.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Chemical pest control without combined solution
Close NBS	- Choice of plants: Indigenous species, Diversity of plant species - Works on soil: soil melioration/improvement, mulching - Integrated and ecological management - Integrated weed management - Urban forests - Habitats and shelters for biodiversity

IV/ References

IV.1 Scientific and more operational references (presented jointly)

ARVALIS INSTITUT DU VÉGÉTAL. ARENA J'ai trouvé une Bête…. http://arena-auximore.fr/jai-capture-une-bete/

BARBARO, Luc et BATTISTI, Andrea, 2011. Birds as predators of the pine processionary moth (Lepidoptera: Notodontidae). *Biological Control*. Vol. 56, pp. 107-114. DOI 10.1016/j.biocontrol.2010.10.009.

DAERA, 2016. Integrated Pest Management | Department of Agriculture, Environment and Rural Affairs. *DAERA* .16 février 2016. https://www.daera-ni.gov.uk/articles/integrated-pest-management

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION. European and Mediterranean Plant Protection Organization (EPPO). https://www.eppo.int/

EUROPEAN COMMISSION. *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council*. *EUR-Lex* .https://eur-lex.europa.eu/eli/reg_impl/2017/1263/oj

GARDINER, Mary M., PRAJZNER, Scott P., BURKMAN, Caitlin E., ALBRO, Sandra et GREWAL, Parwinder S., 2014. Vacant land conversion to community gardens: influences on generalist arthropod predators and biocontrol services in urban greenspaces. *Urban Ecosystems*. Vol. 17, n° 1, pp. 101-122. DOI 10.1007/s11252-013-0303-6.

PLANTE & CITÉ et MINISTÈRE DE L'ENVIRONNEMENT, DE L'ÉNERGIE ET DE LA MER, *Ecophyto PRO : réduire et améliorer l'utilisation des phytos*. https://www.ecophyto-pro.fr

Règlement d'exécution (UE) 2017/1263 de la Commission du 12 juillet 2017 portant mise à jour de la liste des espèces exotiques envahissantes préoccupantes pour l'Union établie par le règlement d'exécution (UE) 2016/1141 conformément au règlement (UE) n° 1143/2014 du Parlement européen et du Conseil, 2017. .32017R1263. http://data.europa.eu/eli/reg_impl/2017/1263/oj/fra

IV.2 Sources used in this factsheet

FOOD AND AGRUCULTURE ORGANIZATION OF THE UNITED NATION. *Plant Production and Protection Division: How to practice Integrated Pest Management.* http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/integrated-pest-management/ipm-how/en/

INRA AVIGNON et PLANTE & CITÉ, 2014. *Guide technique sur la gestion de la Processionnaire du Pin. Préconisations Alterpro.* https://www.ecophyto-pro.fr/data/poster_a3_version_finale.pdf

JALOUX, Bruno et CALDUMBIDE, Catherine, 2015. *Presentation de la protection biologique integrée. Fiche de synthèse*. Plante & Cité. https://www.plante-et-cite.fr/data/fichiers_ressources/presentation_de_la_protection_biologique_integree_nouvelle_version.pdf

LIORZOU, François, 2017. *Conception et gestion différenciée des jardins: pour des aménagements paysagers écologiques*. ISBN 978-2-7430-2302-7.

V/ Author(s)

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I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Integrated weed management (IWM) is an ecosystem-based strategy that combines the available weed control methods such as biological control, weeding, grazing or herbicide application, in a balanced and optimised way. IWM aims at managing weeds on site by maintaining weed constraint under a socially, sanitary and economically acceptable threshold, but not at suppressing weeds. It is to be carried out along with a communication plan for a better acceptance of less-concern weeds (in sanitary or economical terms) and for awareness of invasive species issues. IWM minimizes the use of herbicides and enhances green space ecological functioning. To add value to this NBS, it should be included in an overall integrated and ecological management plan.

IWM is based on careful consideration of all weed control methods available and is always a wise and appropriate combination of techniques that may go as far as herbicides suppression.

Here are some of its possible components.

- ⇨ **Prophylaxis** (prevention management): as a long-term management technique, this set of methods should be a green space conception and management strategy from the beginning. It is nonetheless possible to make this choice at any time, and even after weed invasion. The added value will last and increase over time. See the close NBSs to know more.
  Green spaces design and management planning may be specific (to a weed that is particularly unwanted such as very invasive, or presenting safety issues for example), or be non-specific, which is usually the case.
- ⇨ **Treatment**: curative approach to maintain weed or invasive plants under a tolerance threshold.
  - ➔ Biological control: involves natural-based products (plants, animals, mineral products, microorganisms).
  - ➔ Grazing may be implemented as a routine weeding method or to control invasive species

Sheep as a weeding technique but also as a communication asset © Sarah Meyer, Gondwana

  - ➔ Innovative weeding material

This weeding tool was invented by gardeners of Sèvremoine municipality (France). It damages weeds enough to prevent regrowth but leaves soil undamaged © Bernard Allaire

  - ➔ Chemical control (conventional techniques): herbicides application. This should be regarded as a last resort technique.

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space > 04-1 Biodiversity 07| Public Health and well-being > 07-3 Health	- maintaining or improving quality of existing green spaces - less chemical products released in the environment
Co-benefits and challenges foreseen	01| Climate > 01-1 Climate mitigation 05| Soil management > 05-1 Soil management and quality 06| Resource efficiency > 06-1 Food, energy, water > 06-2 Raw material	- reduction of synthetic petrol-based weed control products saves oil resources and greenhouse gas emissions - maintaining and improving soil biodiversity - reducting the use of synthetic petrol-based pest control products saves energy and oil resources
Possible negative effects	07| Public Health and well-being 08| Environmental justice	- acceptability and tolerance threshold, by inhabitants, users but also municipality teams - for gardeners, the change in their working habits may be confusing; it needs to be explained, understood and accepted - acceptability of wild flowers - some wild flowers might be allergenic plants

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Green space
Impacted scales	Green space Ecological corridors (green strips, etc.) Other green spaces
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Effectiveness of this NBS may not be immediate: from some days/weeks (hand-weeding, grazing, etc.) to the next year in some long-term specific
Life time	IWM is a long-term process: it involves time to ensure lasting benefits with the use of most synthetic weed control products. Use of prophylaxis induces weed management is self-induced and, in most cases, doesn't go as far as a conspicuous weed invasion.
Sustainability and life cycle	IWM is designed as a sustainable approach. Monitoring of weeds and plant health as well as follow up of material are required, but the overall implementation is stable in time with growing efficiency.
Management aspects (kind of interventions + intensity)	- Monitoring and follow up - Weed monitoring at a larger scale (region, country) - Communication towards public for a better acceptance of wild flowers, and to spread the knowledge of exotic invasive species.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality green spaces department - Biological weed control companies - Ecological engineering and consultancy companies

Technical stakeholders & networks	- Specialised green spaces management firms, horticulturist and gardeners, often city intern departments - Ecological engineering and consultancy companies - Communication department: social acceptance and awareness are at the heart of such projects
Social aspects	Green spaces users need to understand the modifications, no matter how small, in the landscape of a place they enjoy. A higher threshold acceptance of minor weed pression is also observed whenever citizen and inhabitants are kept informed. This may be carried out through on-site panels and notice board, and through municipality web-site. Citizen should also be informed about exotic invasive species presence, the threat they induce, and about what is done against these particular weeds.

II.4 Design / techniques/ strategy

Knowledge and know-how involved

- Design green spaces and plant arrangements in a way that limits weeding requirements
- Chose substitute plants, plants, which are not exotic invasive species. They may stem from spontaneous or native species of the area considered or be alien without any overspreading or invasive behaviour.
- Determine a weeding plan:
  - Start a strategy for the acceptance of wild flowers: the better they are tolerated, the less effort is needed to eradicate weeds. Assess wild flower perception by citizen but also by staff. Determine how to positively influence mindsets from negative weed perception (impression of dirty, neglected or dangerous place), towards one of natural and beautiful places in which wild flowers are accepted or even welcome.
  - Determine the areas of the green space where wild flowers are less tolerated (along paths or in a rose garden for instance). Mulching, hand-weeding or other weeding strategies are necessary on these spots.
- In case of weed invasion:
  - Know the weed to better target it: observation, species identification and monitoring of the spread. Be aware that the “weed” status of a plant is context-dependant.
  - Decide, assess and weight up:
    - the level of tolerance (change in the landscape, safety issues about dangerous species like *Heracleum mantegazzianum* that induces skin burns, biodiversity loss risks, etc.) which is socially, economically and environmentally acceptable;
    - the available budget;
    - internal skills, internal material, number of employee, amount of time that is possible to affect to the task;
    - features of the site: type of green space (type of use), size, type of vegetation, users’ frequentation, existing favourable spots or features;
  - Browse the professional press for management feedback and existing strategies, ask other municipalities about their practices for the same issue, seek out expert advice (from specialised green spaces management firms, ecological engineering and consultancy companies, academic research labs), look for official guidance: some weeds are of national or European concern.
  - Define a strategy, carefully considering all available techniques.
  - Carefully plan your strategy in time and space: where to act for best result, when to implement each step.
  - Start implementation. According to weed targeted and level

	of infestation, there may be steps to follow all along the year. For better efficiency, and better sustainability, this NBS should be included in an overall integrated and ecological management plan.
Materials involved	Plant material (substitute plants) Weeding and mowing material and vehicles Animals (if grazing is part of the strategy)

II.5 Legal aspects related

Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council
Local (country) regulations

II.6 Funding Economical aspects

Range of cost	From almost free (long-term weed management strategy already in place, keeping weed population under economic and social injury level) to some thousand euros. Working time is often internal (municipality gardeners, etc.). Material (for mowing cutting, etc.) may already be available for municipality gardeners. Acquisition of different tools may be needed. Example of integrated management of the invasive Japanses Knotweed (*Fallopia japonica*) in Laxou municipality (France): Litterature review, experience feedbacks, methods experiments phase, non-chemical control implementation including goat grazing, communication campaign towards public and information to other municipalities and professionals: 63 640 € (2011-2017)
Origin of the funds (public, private, public-private, other)	Public. Budget to be integrated in green spaces management budget, and/or in biodiversity improvement strategy budget.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

This NBS greatly benefits from integration in an overall integrated and ecological management plan (see related NBSs). IWM may be considered as one aspect of an integrated management plan for green spaces.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors

Success factors	- Early detection of an weed spread - Early detection of the presence of an exotic invasive species - Knowledge of the weed - Careful examination of all methods available, their advantages and disadvantages, their manageability (site-dependant, team-dependant, politics-dependant)
Limiting factors	- Possibly features of the site - Design a strategy without seeking for expert skills or other municipalities' feedback. - Underestimate the price or efforts of some methods, leading to abandoning it

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Chemical weed control without combined solution
Close NBS	- Choice of plants: Indigenous species, Diversity of plant species - Works on soil: soil melioration/improvement, mulching - Integrated and ecological management - Integrated pest management - Urban forests - Habitats and shelters for biodiversity - Mulching

IV/ References

IV.1 Scientific and more operational references (presented jointly)

EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION. *European and Mediterranean Plant Protection Organization (EPPO) website*. https://www.eppo.int/

EUROPEAN COMMISSION. Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. *EUR-Lex* . https://eur-lex.europa.eu/eli/reg_impl/2017/1263/oj

GALLANDT, Eric R., 2004. Soil-Improving Practices for Ecological Weed Management. In: *Weed Biology and Management.* Springer, Dordrecht. pp. 267-284. ISBN 978-90-481-6493-6.

HEYWOOD, V. et BRUNEL, S., 2011. Code de conduite sur l'horticulture et les plantes exotiques envahissantes. Convention relative à la conservation de la vie sauvage et du milieu naturel de l'Europe. *Sauvegarde de la nature*. 2011. N° 162.

PLANTE & CITÉ et MINISTÈRE DE L'ENVIRONNEMENT, DE L'ÉNERGIE ET DE LA MER. Ecophyto PRO : réduire et améliorer l'utilisation des phytos. https://www.ecophyto-pro.fr

Règlement d'exécution (UE) 2017/1263 de la Commission du 12 juillet 2017 portant mise à jour de la liste des espèces exotiques envahissantes préoccupantes pour l'Union établie par le règlement d'exécution (UE) 2016/1141 conformément au règlement (UE) n° 1143/2014 du Parlement européen et du Conseil, 2017. . 32017R1263 http://data.europa.eu/eli/reg_impl/2017/1263/oj/fra

TWIGG, Karen, 2017. "Another Weed Will Come Along": Attitudes to Weeds, Land and Community in the Victorian Mallee. In: *Telling Environmental Histories*. Palgrave Macmillan, Cham. pp. 213-240. Palgrave Studies in World Environmental History. ISBN 978-3-319-63771-6.

IV.2 Sources used in this factsheet

GUÉRIN, Maxime et PROVENDIER, Damien, 2014. *GESTION CURATIVE DES PLANTES EXOTIQUES ENVAHISSANTES. Rapport d'enquête*. Plante & Cité.

GUTLEBEN, Caroline, LEMAIRE, Sophie et PROVENDIER, Damien, 2010. *Gestion des plantes envahissantes, de la flore spontanée, des maladies et ravageurs : Les leviers d'action pour la réduction des interventions phytosanitaires au sein des espaces verts. Dossier technique*. Plante & Cité.

LIORZOU, François, 2017. *Conception et gestion différenciée des jardins: pour des aménagements paysagers écologiques*. ISBN 978-2-7430-2302-7.

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Annabelle BERGOËND	Plante & Cité	Writer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	Integrated and ecological management plan is a balanced economic and ecological vision of public green spaces management. Shifting from the homogeneous application of one management technique to municipality's green spaces as a whole, this NBS regards each green space with its own constraints and needs in connection with the other green spaces. This NBS meets the principles of sustainable development: - Economic: it allows to adapt budget and efforts, thus decreasing costs and working time which are redirected on high demands' spots; - Social: its objectives include quality of life enhancement; - Environmental: it improves biological diversity and decreases environmental risks (decrease of synthetic pest control products' use, etc.) This NBS is included in the local environmental policy. Public green spaces are a window to local political strategy, support and involvement of municipality representatives is essential. NBS "Integrated and Ecological Management: spatial aspect" is closely related to NBS "Integrated and Ecological Management: time and frequency aspects" and constitutes the spatial planning part, which is also the first phase of a management plan creation.

The basis of Integrated and ecological management plan is applying quality codes, which allow planning different management techniques on each site. It is a differentiated approach.
Some of the possible quality codes are listed below.

⇨ **Formal garden** planted with flowers demanding constant monitoring and attention as the risk of plant disease, pest invasion or weed implantation is high and difficult to treat without extensive use of pesticides.

⇨

Flowerbeds in a formal garden ©Soisy-sous-Montmorency-Val'hor

⇨ **Formal park on a site of cultural or historical importance**: these sites are often important for the tourism and visibility and need attention to ensure a constant quality of landscape.

Lawns of an historical building © Baptiste Chassaing, Plante & Cité

⇨ **Temporarily flooded meadows**: some sites are naturally subject to flooding a part of the year.

A flooded meadow © Geneviève Girod, CIME

⇨ Meadow where only unformal path walks are mowed. The space is meant to look natural but planting and vegetation evolution are managed.  *A partially mowed urban meadow © Geneviève Girod, CIME*	⇨ Natural-looking green space  *A grazed urban meadow © Damien Provendier, Plante & Cité*

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban spaces >04.1 Biodiversity >04.2 Urban spaces development	- maintaining or improving quality of existing green spaces maintains and improves biodiversity
Co-benefits and challenges foreseen	05| Soil management >05.1 Soil quality 06| Resource efficiency >06.1 Food, energy, water 08| Environmental justice and social cohesion >08.2 Social cohesion	- maintaining or improving quality of existing green spaces maintains and improves soil biodiversity - reducting synthetic petrol-based pest control products saves oil resources - integration of all working staff in planning and decision; integration of public demands in planning and decisions; integration of the public into inventories through citizen science (crowd-sourced science)
Possible negative effects	07| Public Health and well-being 08| Environmental justice	Risk of an increase in allergenic plants - risk of pest and weed introduction - acceptability and tolerance threshold

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Green space
Impacted scales	Green space Ecological corridors (green strips, etc.) Other green spaces Municipality: this NBS should be implemented at the city scale by including green strip, street trees, etc.

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	This NBS prepares for an immediate implementation of NBS “Integrated and Ecological Management: time and frequency aspects”.
Life time	This NBS prepares for a long-term NBS which stay fully functional as long as it is implemented.

Sustainability and life cycle	This NBS leads to a sustainable set of management which improves over time.
Management aspects (kind of interventions + intensity)	This NBS describes a planning phase. See the related NBS: "Integrated and Ecological Management: time and frequency aspects".
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality green spaces department - Biological pest control companies - ecological engineering and consultancy companies
Technical stakeholders & networks	- horticulturist and gardeners, often city intern departments. - environmental and urban planning engineering and consultancy companies; - communication department: social acceptance is at the heart of such projects; - public research labs in ecology, local natural history museum, etc.
Social aspects	Citizen and inhabitants might be involved in an active way through citizen science (crowd-based science) and they may be involved in consultations and talks about future usage of spaces.
II.4 Design / techniques/ strategy	
Knowledge and how-know involved	- Ask other municipalities for feedbacks for Integrated and ecological management plan implementation. for the same issue, seek out expert advice (from specialised green spaces management firms, ecological engineering and consultancy companies, academic research labs), look for official guidance on managing for the biodiversity for example. - Map the green spaces on the municipality's area. A first inventory is quantitative and may involve a citizen science campaign: o localisation, o dimension, o ecological interest: biological diversity, plant species o type and frequency of management and material used - A second inventory is qualitative: o landscape quality: aesthetic, historic, cultural value o site function and use o frequency usage by the public o management objectives: economic, landscape, environmental, o social demand - From this mapping, define an objective plan according to human, material and economic resources needed. - Assign a quality code to each type of site to meet a management objective. This allows gardeners and managers to know exactly the type of tasks to carry out, their frequency and constitutes a how-to. Each code type is defined in detail. - Monitor and follow up each site. Document the changes, issues faced and how issues are sorted out. - Communicate towards affected teams (gardeners, etc.). Start training sessions, build internal training plan. Gardeners have been working in a conventional way for a long time; that it may take some time to change mindsets and to find the optimized managing way is only natural. This NBS is also about finding the perfectly balanced and adapted management for every site, it leaves place to gardeners' creativity and finding their own cultural practices. Municipal teams and citizen mindsets need to change from impressions of dirty, unmanaged and dangerous places, towards the will to value urban nature, wild flowers and wild animals.
Materials involved	GIS software, maps Environmental inventory equipment Local historical, cultural and agricultural documents and literature.

II.5 Legal aspects related
Legal aspects are related to biological pest control: - *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council* - Local (country) regulations - It is mandatory to file an authorization's application before the introduction of alien beneficial organisms.

II.6 Funding Economical aspects	
Range of cost	This fist phase of an integrated and ecological management plan creation may the most expensive part of a management plan life cycle. Cost of inventories differ depending of the person or organism. This work may be internal. A GIS software is needed and training is necessary, but internal skill may be available. As an example, the municipality of Albi (France, mid-size town) carried out an external insect inventory. Budget involved was 6 000€.
Origin of the funds (public, private, public-private, other)	Public. May be integrated in environmental budget (biodiversity improvement policy).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Integrated and ecological management plan usually includes many NBSs related to Strategies and actions such as urban green space management, urban planning, monitoring etc. (Integrated pest and weed management, integration of flooding, composting, etc.), but also most of objects such as parks and gardens, structures associated with urban networks, polluted areas, erosion control, choice of plants, etc. As an integrated way of planning and managing it is inherently part of all urban strategies and processes about urban nature at any scale and it includes any patches of urban nature.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Proper documentation, proper knowledge A clear view of the objectives. Integrating all the sustainable development aspects: economic, social, ecological.
Limiting factors	Lack of consideration of demands and constraints for each site.
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Classical management plans (no differentiation by site, usage or needs) Extensive use of pest-control products.
Close NBS	As explained in the II.7 Combination part, this NBS is inherently part of all NBSs related to urban strategies and processes about urban nature at any scale and includes most of NBSs integrating patches of urban nature.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

ARNBERGER, Arne, EDER, Renate, 2012. The influence of green space on community attachment of urban and suburban residents. *Urban Forestry & Urban Greening*. Vol. 11, n° 1, pp. 41-49. DOI 10.1016/j.ufug.2011.11.003.

BOUTAUD, Jacques, 2015. *La taille raisonnée des arbustes d'ornement. Fiche de synthèse*. 2015. Plante & Cité.

EUROPEAN COMMISSION. *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. EUR-Lex*

GUTLEBEN, Caroline, LEMAIRE, Sophie, PROVENDIER, Damien, 2010. *Gestion des plantes envahissantes, de la flore spontanée, des maladies et ravageurs : Les leviers d'action pour la réduction des interventions phytosanitaires au sein des espaces verts. Dossier technique*. Plante & Cité.

LEPCZYK, Christopher A., ARONSON, Myla F. J., EVANS, Karl L., *et al,* 2017. Biodiversity in the City: Fundamental Questions for Understanding the Ecology of Urban Green Spaces for Biodiversity Conservation. *BioScience*. Vol. 67, n° 9, pp. 799-807. DOI 10.1093/biosci/bix079.

LIORZOU, François, 2017. *Conception et gestion différenciée des jardins: pour des aménagements paysagers écologiques*. ISBN 978-2-7430-2302-7.

MARTIN, Bertrand, 2010. *Politique de réduction à la source et de valorisation des déchets verts. Fiche de synthèse*. 2010. Plante & Cité.

NIEMELÄ, Jari, 1999. Ecology and urban planning. *Biodiversity & Conservation*. 1 janvier 1999. Vol. 8, n° 1, pp. 119-131. DOI 10.1023/A:1008817325994.

PICKETT, S. T. A., CADENASSO, M. L., GROVE, J. M., *et al.*, 2001. Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas. *Annual Review of Ecology and Systematics*. Vol. 32, n° 1, pp. 127-157. DOI 10.1146/annurev.ecolsys.32.081501.114012.

PLANTE & CITÉ, MINISTÈRE DE L'ENVIRONNEMENT, DE L'ÉNERGIE ET DE LA MER. *Ecophyto PRO : réduire et améliorer l'utilisation des phytos*. [online]. https://www.ecophyto-pro.fr

IV.2 Sources used in this factsheet

BAPTISTE CHASSAING, 2014. *La gestion différenciée : méthodologie de mise en oeuvre. Fiche de synthèse*. Plante & Cité.

NORD NATURE CHICO MENDES. Gestion différenciée. *Gestion Différenciée* [online]. https://www.gestiondifferenciee.org/

ZITKOVIC, Maja, ICLEI LOCAL GOUVERNMENTS FOR SUSTAINABILITY, 2008. *Managing green spaces for urban biodiversity. Factsheet.* Countdown 2010.

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Annabelle BERGOËND	Plante & Cité	Writer
Marjorie Musy	Cerema	Reviewer

Strategies & Actions > Urban green spaces management – Direct human interventions

> Integrated and Ecological Management: time and frequency aspects

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Integrated and ecological management plan is a balanced way to meet economic, social and ecological demands and constraints by rationalising costs and optimizing processes. Shifting from the homogeneous application of one management technique to municipality's green spaces as a whole, this NBS regards each green space with its own constraints and needs in connection with the other green spaces. This NBS meets the principles of sustainable development: - Economic: it allows to adapt budget and efforts, thus decreasing costs and working time which are redirected on high demands' spots; - Social: its objectives include quality of life enhancement; - Environmental: it improves biological diversity and decreases environmental risks (decrease of synthetic pest control products' use, etc.) NBS "Integrated and Ecological Management: time and frequency aspects" is closely related to NBS "Integrated and Ecological Management: spatial aspect". It constitutes a second phase of a management plan creation.

The basis of Integrated and ecological management plan is to apply quality codes, which allows planning different management techniques with different intensity and frequency. It is a differentiated approach. Some of the possible quality codes related to management frequency and intensity level are listed below.

⇨ **Hedges of box tree** such as in formal French gardens demanding a very high level of management (intensive pruning, etc.), and a constant monitoring and attention as the risk of plant disease, pest invasion or weed implantation is high and difficult to treat.

Highly managed hedge ©Val'hor

⇨ **Meadow** where only unformal path walks are mowed. Interventions are of low intensity and frequency. The space is meant to look natural but planting and vegetation evolution are managed.

A partially mowed urban meadow © Geneviève Girod, CIME

⇨ **Temporarily flooded meadow:** some sites are naturally subject to flooding during a part of the year. Allowing water to temporarily take over without management saves money and avoids heavy infrastructure's building. Planting and public equipment such as benches or fences need to adapt to this cycle. Management in such sites is very seasonal and varies from no management at all to grazing or mowing while repairing some equipment along the year.

A flooded meadow in which a fenced path is below water during several months © Annabelle Bergoënd, Plante & Cité

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban spaces >04.1 Biodiversity >04.2 Urban spaces development	- maintaining or improving quality of existing green spaces maintains and improves biodiversity
Co-benefits and challenges foreseen	05| Soil management >05.1 Soil quality 06| Resource efficiency >06.1 Food, energy, water 08| Environmental justice and social cohesion >08.2 Social cohesion	- maintaining or improving quality of existing green spaces maintains and improves soil biodiversity - reducting synthetic petrol-based pest control products saves oil resources - integration of all working staff in planning and decision; integration of public demands in planning and decisions; integration of the public into inventories through citizen science (crowd-sourced science)
Possible negative effects	07| Public Health and well-being	Risk of an increase in allergenic plants - risk of pest and weed introduction - acceptability and tolerance threshold

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Green space
Impacted scales	Green space Ecological corridors (green strips, etc.) Other green spaces Municipality: this NBS should be implemented at the city scale by including green strip, street trees, etc.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Due to the multiplicity of managements involved and their nature (implementation at specific times in the year), a one-year period is a minimum to expect NBS to fully work. It is to be added to the period of inventory and mapping.
Life time	This is a long-term NBS, which stay fully functional as long as it is implemented.
Sustainability and life cycle	This NBS is a sustainable set of management which improves over time.
Management aspects (kind of interventions + intensity)	Kind of interventions and intensity are specific to each quality code. They are described in the management plan.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality green spaces department - Biological pest control companies - Ecological engineering and consultancy companies
Technical stakeholders & networks	- Horticulturist and gardeners, often city intern departments. It must be fully understood by the working teams (gardeners, etc.) and to be implemented with it to be effective; - Ecological and environmental engineering and consultancy companies; - Communication department: social acceptance is at the heart of such projects; - Public research labs in ecology, local natural history museum, etc.

Social aspects	A change in management techniques may lead to a change in the landscape. Citizen and inhabitants must at least be informed through on-site panels and notice board, and through municipality web-site. They might be involved in a more active way through citizen science (crowd-based science). Green spaces are known social link facilitators (Arnberger and Eder, 2012).

II.4 Design / techniques/ strategy

Knowledge and how-know involved	Assign a quality code to each type of site to meet a management objective (see the related NBS: "Integrated and Ecological Management: spatial aspect". This allows gardeners and managers to know exactly the type of tasks to carry out, their frequency and constitutes a how-to. Each code type is defined in detail. Affect adapted budget and working time to each quality code. Over time, this allows reductions: ○ of cost investment in pest or disease control; ○ of mowing and pruning frequency; ○ of water use; ○ of transfer frequency to and fro less managed sites; ○ of oil use; ○ of input use; ○ of waste disposal; ○ etc. - Specific managements of this NBS include delayed mowing to allow pollen- and nectar-producing plants to bloom, differentiated mowing (more frequent along paths or roads, etc.), wise pruning to decrease plant diseases risks and extend shrub and trees lifespan, allowing natural flooding, integrated pest management and integrated weed management, preserving or creating habitats and shelters for biodiversity, enhancing soil quality, planting sturdy plant varieties, use of grazing animals, reuse of green waste, mulching, composting, etc. -This NBS integrates some forgotten methods and features such as local soil knowledge, agronomic functioning, plant needs, art of gardening, etc. It includes biodiversity conservation and promotion of natural and historic local features. As it promotes better ecological functioning, it leads to decreasing risks of pest or weed proliferation. Thus, it may go as far as no pesticide use on the municipality area. Monitor and follow up each site. Document changes, issues faced and how issues are sorted out. Communicate towards affected teams (gardeners, etc.). Start training sessions, build internal training plan. Gardeners have been working in a conventional way for a long time; that it may take some time to change mindsets and to find the optimized managing way is only natural. This NBS is also about finding the perfectly balanced management for every specific site, it leaves place to gardeners' creativity and finding their own cultural practices. Municipal teams and citizen mindsets need to change from an impression of dirty, unmanaged and dangerous places, urban nature, wild flower, wild animals may be valued.
Materials involved	Usual green spaces management material and vehicles. Some new material such as thermal weeding material, etc.

II.5 Legal aspects related
Legal aspects are related to biological pest control: - *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council* - Local (country) regulations - It is mandatory to fill an authorization's application before the introduction of alien beneficial organisms.

II.6 Funding Economical aspects	
Range of cost	Integrated and ecological management plan should not be regarded as cost-demanding, but rather as cost-saving. During the first phase of the NBS and then yearly, budget which was previously allocated to green space management is thought through and re-distributed to tasks and spaces in an optimised way. This dynamic process may keep budget as it was or may even decrease it. It re-allocates money in a more visible and efficient way to where it is needed. For example, costs of disposing of green waste (from mowing, pruning, etc.) can be reduced by reusing plant material (chipping and mulching, or creating insect shelters for example). In terms of working time costs, the municipality of Rennes (France, mid-size city), gives an example (average figures for year 2012): - 2 800 hours /hectares/year for a very formal garden planted with flowers demanding a very high level of management - 1 200 h/ha/y for a formal garden with a high level of management - 800 h/ha/y for a "transitional" green space - 250 h/ha/y for a cottage-looking green space - 90 h/ha/y for a natural-looking green space
Origin of the funds (public, private, public-private, other)	Public. Budget usually allocated to green spaces management. May also be integrated in environmental budget (biodiversity improvement policy).

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Integrated and ecological management plans usually include many NBSs related to Strategies and actions such as urban green space management, urban planning, monitoring etc. (Integrated pest and weed management, integration of flooding, composting, etc.), but also most of objects such as parks and gardens, structures associated with urban networks, polluted areas, erosion control, choice of plants, etc. As an integrated way of planning and managing it is inherently part of all urban strategies and processes about urban nature at any scale and it includes any patches of urban nature.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Proper training of working teams. It has to be fully understood by the working teams (gardeners, etc.) and to be implemented with it to be effective.
Limiting factors	Lack of inventories and mapping pre-implementation. Lack of monitoring and follow-up.

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Classical management plans (no differentiation by site, usage or needs) Extensive use of pest-control products.

Close NBS	As explained in the II.7 Combination part, this NBS is inherently part of all NBSs related to urban strategies and processes about urban nature at any scale and includes most of NBSs integrating patches of urban nature.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

ARNBERGER, Arne, EDER, Renate, 2012. The influence of green space on community attachment of urban and suburban residents. *Urban Forestry & Urban Greening*. Vol. 11, n° 1, pp. 41-49. DOI 10.1016/j.ufug.2011.11.003.

BOUTAUD, Jacques, 2015. *La taille raisonnée des arbustes d'ornement. Fiche de synthèse*. 2015. Plante & Cité.

EUROPEAN COMMISSION. *Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 updating the list of invasive alien species of Union concern established by Implementing Regulation (EU) 2016/1141 pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council. EUR-Lex*

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LEPCZYK, Christopher A., ARONSON, Myla F. J., EVANS, Karl L., *et al,* 2017. Biodiversity in the City: Fundamental Questions for Understanding the Ecology of Urban Green Spaces for Biodiversity Conservation. *BioScience*. Vol. 67, n° 9, pp. 799-807. DOI 10.1093/biosci/bix079.

LIORZOU, François, 2017. *Conception et gestion différenciée des jardins: pour des aménagements paysagers écologiques*. ISBN 978-2-7430-2302-7.

MARTIN, Bertrand, 2010. *Politique de réduction à la source et de valorisation des déchets verts. Fiche de synthèse*. 2010. Plante & Cité.

NIEMELÄ, Jari, 1999. Ecology and urban planning. *Biodiversity & Conservation*. 1 janvier 1999. Vol. 8, n° 1, pp. 119-131. DOI 10.1023/A:1008817325994.

PICKETT, S. T. A., CADENASSO, M. L., GROVE, J. M., *et al*., 2001. Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas. *Annual Review of Ecology and Systematics*. Vol. 32, n° 1, pp. 127-157. DOI 10.1146/annurev.ecolsys.32.081501.114012.

PLANTE & CITÉ, MINISTÈRE DE L'ENVIRONNEMENT, DE L'ÉNERGIE ET DE LA MER. *Ecophyto PRO : réduire et améliorer l'utilisation des phytos*. [online]. https://www.ecophyto-pro.fr

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BAPTISTE CHASSAING, 2014. *La gestion différenciée : méthodologie de mise en oeuvre. Fiche de synthèse*. Plante & Cité.

NORD NATURE CHICO MENDES. Gestion différenciée. *Gestion Différenciée* [online]. https://www.gestiondifferenciee.org/

ZITKOVIC, Maja, ICLEI LOCAL GOUVERNMENTS FOR SUSTAINABILITY, 2008. *Managing green spaces for urban biodiversity. Factsheet.* Countdown 2010.

V/ Author(s)

Name	Institution / company	Writer/ reviewer
Annabelle BERGOËND	Plante & Cité	Writer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Habitats and shelters for biodiversity are designed to attract, shelter or provide food to a specific type of organism (for example ladybirds, bumblebees, swifts, robins), a type of animal (for example ground insects, bats), or to a micro-ecosystem. They enhance biodiversity on the area they are part of. Most efficient habitats and shelters provide several or all the followings to varied species: a breeding site, a resting site for the day/night or in winter, a nesting site, a perching site, food resources (either directly, or by feeding preys). They may consist in a site (from small like a stack of dead branches to quite large like low maintenance hedge), or an artificial object or group of objects like hollow stems disseminated on the site or a bird nest box. Besides the obvious benefits for fauna and flora preservation and enhancement *per se*, shelters and habitats also preserve, promote or attract organisms which are of great value in pest management, plant diseases control, and/or pollination. As such, they are essential tools for green spaces managers.

Habitats and shelters for biodiversity are diverse. They range from non-specific to specific, depending on the purpose, the potentialities of the site, the level of involvement.
Non-specific habitats and shelters are the most efficient in terms of biodiversity enhancement because they provide food and shelter to micro-ecosystems (M. Guérin, 2016).
Some examples of this NBS include:

⇨ **Dead wood:**
Shelters a wide range of xylophagous insects, fungi, mosses, and microorganisms. They find shelter and resources inside (mining species, decomposing organisms, etc.), on it (fungi, mosses, plants, insects etc.) or feed out of these organisms (insects, birds, bats, etc.).
Fauna and flora benefiting from dead wood decomposition build up a whole ecosystem, becoming a biodiversity reserve at the green space scale.

Decomposing dead wood, with fungi developing on it. ©HervéB. I-Naturalists

⇨ **Spot planted with vegetation of different age, size, type and features:**
Offers complementary habitats for a wide range of fauna and flora species fulfilling their requirements throughout the year. A wide range of insects need different types of food and shelter at each stage of their life cycle. This NBS provides different nesting places, resting sites, honey and nectar, etc. throughout the year. Many insects are valuable pest control agents, whether they are released for that purpose or already present on site. Insect larvae are often pest predators or pest parasites. Other animals like birds also find shelter, hide, rest in the winter or feed (out of insects, fruits, etc.) out of various compounds of the NBS.

Stratified vegetation of a Mediterranean hedge in green space managed ecologically (EcoJardin) © Girod G., CIME

⇨ **Standing dead trees** (without issue for public safety) **and trees displaying hollows or cavities:**
A wide range of organisms depends on dead or dying trees: cavity-nesting birds or insects, and larger organisms feeding on them. It also provides perching sites. Conserving them on site ensures improvement of these populations

Standing dead tree in a wildlife park, Seeteufel ©Seeteufel

⇨ **Habitat for wild bees**
There is a variety of wild bees with different nesting requirements. Most of them are solitary. Some of them nest in wood or stems, many dig holes underground. Preserving or creating favourable habitats is successfully combined with wild flower beds enhancement proving food resources.

Reproduction site for bee species which nest in the sand © Lille city France

⇨ **Artificial shelters**
These shelters are usually specific to a species or a type of animal. Their efficacy is generally lower than other types mentioned previously. This is particularly useful in various cases including when there is a communication or educational strategy in which insect hotels or nest boxes are displayed or built by citizen.

Insects hotel displaying various shelters to attract different species ©M. Guérin, Plante & Cité

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban spaces > 04.1 Biodiversity > 04.2 Urban spaces development and regeneration	- Improving biodiversity by providing habitat and food for insects and fauna. - Improvement of soil biodiversity for most of the non-specific apparatus
Co-benefits and challenges foreseen	05| Soil management > 05.1 Soil management and quality 06| Resource efficiency > 06.3 Waste > 06.4 Recycling	- Improving soil quality through improvement of its biodiversity - Improving material waste management through reuse of dead wood, pruning waste, stones, pottery fragments, etc.
Possible negative effects	07| Public Health and well-being	- In some cases: provide habitat for undesired insect species - In some cases: presence of allergenic plants

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales

Scale at which the NBS is implemented	Object scale
Impacted scales	Mostly limited to building plot or immediate neighbourhood

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	Depending on the type of habitat, the type of fauna targeted (if applicable), and the time of implementation, effects may be immediate or may take some days, weeks, or months. Benefit is immediate for sheltered species already present on site (giving them better access to resources and shelters). If the shelter is specific to a bird, a bat or some insects, benefit is immediate or delayed some days or weeks (time needed to be found by the target). Sometimes, accurate season of implementation matters: shelter efficiency will be delayed another season if implementation is not carried out at the right time. Whenever the habitat is of sufficient complexity and provides a diversity of food resources throughout the year, benefit is immediate for at least some species, and growing with time. For some specific bird nest boxes or bat boxes, the benefit may be inexistent if design or location are not correctly chosen.
Life time	Life time of built objects like insect hotels or nest boxes follows the life time of the materials (wood, etc.) they are made of. Life time of most habitats and shelters is long: a stack of stones stays effective if not removed, a stack of wood needs replacement only after some years.
Sustainability and life cycle	Quality and effectiveness of habitats inspired by nature improve over time (Chapelin-Viscardi, 2017). More supply may be needed from time to time, mostly provided by leftovers (pruning waste, mowing waste, trees grown old, stones collected on site, etc.). Most organisms need different conditions at different times of the year, but it is not always possible to fulfil all these needs. Some habitats and shelters are used by some species only some time of the year or even not every year (bats nest for example), which does not make them inefficient. Sustainability of habitats and shelters is a requisite for persistence of fauna and flora population.
Management aspects (kind of interventions + intensity)	No pesticides, no chemicals applied to or close to this NBS. Most of habitats and shelters need to be kept away from usual management of green spaces. Yearly monitoring may include checking and sometimes repair, additional supply of matter, or some low intensity management in some cases.

II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Municipality green spaces department - Citizens through civic activism for urban gardening
Technical stakeholders & networks	- Specialised green spaces management firms, horticulturist and gardeners, often city intern departments - Local nature conservation charities - Ecological engineering and consultancy companies - Communication department: social acceptance is at the heart of such projects
Social aspects	Citizen and inhabitants must at least be informed through on-site panels and notice board. This NBS would benefit from citizen implication.

II.4 Design / techniques/ strategy	
Knowledge and know-how involved ➔	**(1) Use the site's assets to design and plan the NBS:** - Identify the characteristics (type of vegetation, public frequentation, etc.) and potential - Determine the species already present on site - Identify the spots displaying the most favourable features: dead wood; spot planted with vegetation of different age, size, type with melliferous plants; an old stone wall (not pointed), etc. - From the previous results, assess the type of biodiversity which will be more easily promoted on this site, and decide a strategy.

	(2) Develop and adapt pre-existing habitats according to the selected strategy. This should be integrated into the green space management plan to ensure handiwork and waste management optimisation as well as long term coherence. Display and arrange components to better integrate the NBS in the landscape. **(3) Creation of artificial habitats may be undertaken in addition:** - in the case of a distinctive species conservation or restauration strategy - in the case of biocontrol implementation, to especially promote a specific pests predator or parasite - to maximise other habitats and shelters efficiency - as a part of an educational campaign It is essential to get scientific advice from, or even to build up a decisional or operational team with, ecological engineering or consultancy company, or nature conservation charity. **(4) Communicate** Citizen involvement is part of the long-term success of this NBS. It is also an appropriated means to environmental education.
Materials involved	Mostly leftovers from green spaces management (wood and dead wood, branches, mulch, grass clippings, hay, stones, sand, etc.). Wood, nails and some other building material (like bricks, stones, stems, …) may be bought or provided by using upcycled materials to build some birds, bats or insect shelters. Already built nest boxes or insect hotels may be bought if needed. For habitats involving vegetation, sowing or planting indigenous flora is preferred for a better adaptation and because they offer more energetic resources to the wild fauna already adapted to it.

II.5 Legal aspects related

Safety of green space users needs to be ensured.
When educational campaigns involve building shelters with children, safety has to be ensured.

II.6 Funding Economical aspects

Range of cost	Very low. From almost free except for the working time of gardeners or other staff involved (planting stacks of wood, piles of sand, etc.), to some hundred euros (an already built nest box : 10-50 €; a large already built insects hotel : 50-150 €; a program for wild bees conservation and restauration : 552 € from the example of the city of Lille, "Capitale de la Biodiversité" 2016). Keeping habitats and shelters away from overall management, and the reuse of leftovers may in some cases save management and waste disposal costs.
Origin of the funds (public, private, public-private, other)	Public, to be integrated in green spaces management budget, and/or in biodiversity improvement strategy budget.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Value of this NBS is increased by combining it with an integrated and ecological management plan, or with an integrated pest management.

Artificial birds and insect shelters displayed in an integrated and ecologically managed site ©Val'hor

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	There is a connection between the species attracted and the site's characteristics. Learn how to get advantage of your site's assets.
Limiting factors	Site's limitations. Site maintenance and management requirements (if not considered at early stage)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	For biodiversity improvement: none For pest control: pesticide use (which may reduce the other component of this NBS' goal: biodiversity improvement).
Close NBS	- Hedge and planted fences - Woods - Choice of plants: Indigenous species, Diversity of plant species - Works on soil: soil melioration/improvement, mulching - Integrated and ecological management - Integrated pest management - Semi-intensive green roof

IV/ References

IV.1 Scientific and more operational references (presented jointly)
AMY, Sam R., HEARD, Matthew S., HARTLEY, et al., 2015a. Hedgerow rejuvenation management affects invertebrate communities through changes to habitat structure. Basic and Applied Ecology. Vol. 16, n° 5, p. 443-451.
FLANDIN, J. et PARISOT, Chr., 2016. Guide de gestion écologique des espaces collectifs publics et privés. Natureparif.
GARDINER, Mary M., PRAJZNER, Scott P., BURKMAN, Caitlin E., et al., 2014. Vacant land conversion to community gardens: influences on generalist arthropod predators and biocontrol services in urban greenspaces. Urban Ecosystems. Vol. 17, n° 1, p. 101-122.
PEACH W. J., VINCENT K. E., FOWLER J. A. et GRICE P. V., 2008. Reproductive success of house sparrows along an urban gradient. Animal Conservation. Vol. 11, n° 6, p. 493-503.
SADLER J. P., SMALL E. C., FISZPAN H., et al., 2006. Investigating environmental variation and landscape characteristics of an urban–rural gradient using woodland carabid assemblages. Journal of Biogeography. 28 avril 2006. Vol. 33, n° 6, p. 1126-1138.
SAUERBREI, Ralf, AUE, Birgit, KRIPPES, et al. 2017. Bioenergy and biodiversity: Intensified biomass extraction from hedges impairs habitat conditions for birds. Journal of Environmental Management. 1 février 2017. Vol. 187, p. 311-319.
IV.2 Sources used in this factsheet
CHAPELIN-VISCARDI, Jean-David, 2017. Les haies et les aménagements d'arbres en ville, des habitats utiles pour les insectes. Fiche technique. 2017. Plante & Cité.
GUÉRIN, Maxime et PROVENDIER, Damien, 2017. Aménagements paysagers & conservation de la faune utile. Fiche de synthèse. 2017. Plante & Cite.
GUÉRIN, Maxime, 2014. Attractivité des plantes pour les auxiliaires. Synthèse sur les interactions Plante/Insecte. 2014. Plante & Cité.
GUÉRIN, Maxime, 2017. Aménager pour la biodiversité en toute simplicité. In : Aménager et gérer avec frugalité. Préserver les ressources en faisant mieux avec moins. Ecouflant : Plante & Cité. Pp. 67. &. ISBN 978-2-9552143-3-6.
MICHAUT, Jean-Emmanuel, 2016. Mesures conservatoires de la faune auxilliaire des jardins : comment protéger et attirer les insectes ? Fiche de synthèse. 2016. Plante & Cité.

V/ Author(s)

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➢ Waste management

> COMPOSTING

I.1 Definition and different variants existing

Definition	Composting is a natural method for processing solid waste in which organic material is broken down by microorganisms in the presence of oxygen to a point where it can be safely stored, handled and applied to the environment as a fertilizer and soil amendment. Organic material has a twofold origin: – Community: urban allotments, small-scale urban livestock, nearby restaurants, markets, fruit stores, etc. – Industry processes: crops or agro-industry waste. The objective is to close the loop on organics recovery. Likewise, this NBS has educational and engagement purposes. It could be helped by chickens because chickens clean the compost of weeds, rodents and insects, while the compost helps to warm the animals and feed the birds.

Different variants existing

There are four ways of composting:

=> Vermicomposting

Red worms in bins feed on food scraps, yard trimmings, and other organic matter to create compost.

Vermicomposter
© CARTIF

Worms in a vermicomposter
© CARTIF

Leachate collection
© CARTIF

=> Onsite composting
Small amounts of wasted food can compost onsite. Another option is place organic waste directly on the ground or slightly mixed with soil.


Small amount of compost in urban orchard © CARTIF


Small amount of organic waste composting
© CARTIF

=> Pile composting
In aerated static pile composting, organic waste mixed in a large pile. In order to aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added, so that air can cross from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Air blowers might be activated by a timer or a temperature sensor.


Source: http://maf-compostingsystems.de/


Composting with chickens
Source: Vermont compost company

=> House and community composting (HCC)
In-vessel composting can process large amounts of waste without taking up as much space as the windrow method and it can accommodate virtually any type of organic waste. This allows a good control of the environmental conditions such as temperature, moisture and airflow.

House composting
© CARTIF

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space 04-2 Urban space development and regeneration 05| Soil management 05-1 Soil management and quality 06| Resource efficiency 06-3 Waste 06-4 Recycling 11| Green Economy 11-1 Circular economy	– Maintain the existing biodiversity of soils (macro-fauna, meso-fauna and micro-fauna) – Preservation of biodiversity – Increase in soil organic matter – Improved circularity via the use of NBS to dispose of waste while reusing it as nutrition, etc. – Reduce and improve the use of waste and by-products / Improve recycling efficiency (this will reduce the generated amount of waste, and will increase the recycling rate and enhance the circular economy) – Can create employment if organized
Co-benefits and challenges foreseen	07| Public health and well-being 07-2 Quality of life	– Citizens are participants in the management of the NBS – Educational activities
Possible negative effects	07| Public health and well-being 07-2 Quality of life	- Unpleasant smells - Weeds - Pests - Citizenship complaints

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Community composting could be implemented at: – Neighbourhood/district level – City level
Impacted scales	The scales impacted will depend on the size/dimension of the NBS installed. A small community composting (neighbourhood/district level) could deliver a city scale impact.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	0-2 years => linked with the logistic and the effectiveness of recovery waste processes. Also, it will be directly related to the citizens' participation.
Life time	8-10 years This parameter depends mainly on the composting facilities conservation. However these facilities can be restored along the time increasing the life time of the NBS.
Sustainability and life cycle	Community composting activities are sustainable NBS, due to the materials and constructions elements used are from recycled materials (mainly wood and some metallic elements), which could be incorporated to the recycling chain after life cycle.
Management aspects (kind of interventions + intensity)	It will be necessary a refurbishment of the land in the installation place. In the same way, it will be necessary to ensure the accesses across which the composting structure can be fed it. Also, it will be necessary a water connexion in order to provide humidity to the composting process. On the other hand, it will be necessary a space to manage the waste and to extract the obtained compost. It will be necessary to know the beneficiary of the final product, for instance: they can be the neighbours, urban gardens or municipal gardens.
II.3 Stakeholders involved/ social aspects	
Stakeholders involved in the decision process	- Local authorities - Natural Resources Management entities - The Citizenship - Waste providers (restaurants, markets, fruit stores, agri-food industries, etc.) - NGOs and other communal entities - Land owners, land co-owners (in case of a joint ownership property) - Tenants - Final users
Technical stakeholders & networks	- Technicians from the municipality - Agricultural engineers - Architects and town planners - Specialized green spaces management companies, horticulturist and gardeners - Final users The technical stakeholder's network for this kind of NBS is well identified.
Social aspects	- It will be necessary a deep study about the acceptation of this NBS - It will be necessary a wide information campaign - It will be necessary to associate this NBS with activities related to social cohesion, local job creation, promotion of mental and physical health in this spaces, educational activities, etc. - It will be very important to create co-creation processes linked to this NBS (participatory process)

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- Municipality and local authorities' involvement - Base-line of the city - Social features of the place to be used - Urban landscape criteria - Selection and design of the location place - Development of a monitoring program as strategy to measure impacts of the NBS - Establishment of a maintenance program - Establishment of by-products reuse program - Establishment of final product use plan
Materials involved	- Composters (made of recycled wood) - Organic matter (food scraps, yard trimmings, etc.) - Watering/irrigation material

II.5 Legal aspects related

It will be necessary to take into account the national and local regulation related to urban farming and composting activities and regulatory framework regarding the use of waste to be composted. In the same way, it will be necessary to consider the legal aspects linked to urbanistic requirements (accesses, emergency entries, etc.).

II.6 Funding Economical aspects

Range of cost	It is important to remark that the cost of this NBS depends on many factors, being all of them really uncertain and different regarding cities and countries, so it depends on the market price. The budget and maintenance can be € 0 if it were done directly on the ground, or the cost of doing it yourself and maintaining it would be mostly invested in labour. The cost could be at least € 50 if the composter is bought and if a good maintenance is carried out. Other costs are not necessary. Organic material will be provided from house, livestock, plots, restaurants, etc. The cost of operating and maintenance could be really low if the activity has the engagement of specific companies or organizations, which want to promote social activities in cities. The costs related to buy animals could imply 50€/year. Initial operating estimated cost: € 500
Origin of the funds (public, private, public-private, other)	Usually, funds are from municipalities, since they are in charge of the administration and management of places where community composting could be installed. Nevertheless, occasionally the management of urban forest is carried out by other kind of entities (NGOs) which have different funding ways.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

Community composting activities can be combined with many different NBS:

- Urban orchards, urban allotments
- Pollinator verges
- Smart soils
- Natural pollinator's modules
- Green fences
- Wood allotments
- Forest school
- Forest church
- NBS Educational activities
- NBS Awareness activities

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Right composting facilities construction - Citizens participation/collaboration - Companies participation/collaboration - Right location - Management plan - Social acceptance
Limiting factors	- Right location - Difficulties of management - Social non-acceptance - Governance and authorizations - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	It does not apply
Close NBS	- Shade trees - Cooling trees - Green noise barriers - Urban orchard - Pollinator verges - Natural pollinator's modules - Green fences - Urban farming activities - Wood allotments - Forest school - Forest church - GI for Physical and mental health - NBS Educational activities - NBS Awareness activities

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Jamie B. Kirkpatrick, Aidan Davison, *Home-grown: Gardens, practices and motivations in urban domestic vegetable production.* Landscape and Urban Planning, Volume 170, 2018, Pages 24-33, ISSN 0169-2046

Bueno Mariano, *Manual Práctico del Huerto Ecológico.* La Fertilidad de la Tierra. 2010, Pages 102-111, ISBN 13: 978-84-936308-8-1

IV.2 Sources used in this factsheet

Urban GreenUP project "New Methodology to Re-naturing Cities through Nature-Based Solutions (NBS)". This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730426.

Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C.,Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L. and Calfapietra, C. (2017) An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom

http://www.merseyforest.org.uk/

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- **Urban (green) spaces management**
- **Protection and conservation strategies**

> LIMIT OR PREVENT ACCESS TO AN AREA

> LIMIT OR PREVENT SOME SPECIFIC USES AND PRACTICES

> Limit or Prevent Access to an Area

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing	
Definition	This NBS is the limitation of access to certain fragile areas in the denser urban fabric where massive human presence has negative effects to the natural or desired operation of the area. The access can be limited in time (for example daytime, part of the year, several years, only by dry weather…), to a number of visitors per period, or completely restricted.

Different variants existing

Four types can be identified, depending of their nature:

=> Nature conservation areas

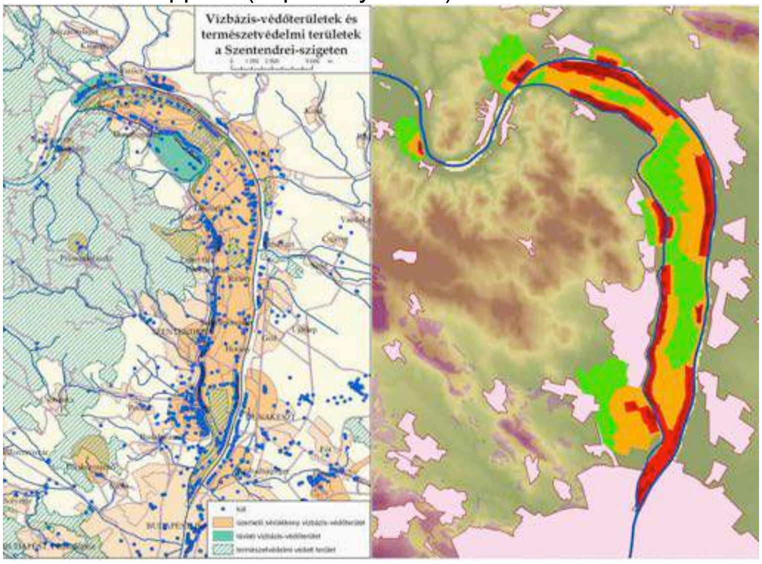
Areas of natural importance within the urbanised area with endangered species

Sas-hegy Látogató Központ (Sas- mountain Visiter Center) Budapest

Photo source :http://www.arkonbokron.hu/news/viewnews/437-veszelyben-a-sas-hegy-elovilaga, https://www.programturizmus.hu/partner-budai-sas-hegy-termeszetvedelmi-terulet.html?f=10&fs=d

Petite Amazonie, Nantes (France) Natura 2000 zone in Nantes - Restricted to a number of visitors (organized visits) per year. (Source: Nantes Métropole & SEVE Nantes).

=> Natural resource conservation areas
These areas serve as sources of supplies (especially water) for the urban area.



Southern Szentendre Island is a sensitive water base area, Hungary Map source: https://dunaiszigetek.blogspot.hu/2015/01/ingyenes-vizum-dunai-szigetekre.html

=> Limited access security areas
These areas serve for some protection purposes, either military, environmental or other.

Tétényi plateau, Budapest – former military air defense territory Photo source: http://terep-jaro.blogspot.hu/2014/05/a-tetenyi-fennsik-tavaszi-pompaja.html

Storm water reservoir is under construction, Érd, Hungary Photo source: http://erdmost.hu/2017/12/12/folytatodik-a-zaportarozo-epitese/

=> Small scale restricted areas to protect habitat
These small size areas are to protect and secure the appropriate environment in the urbanized land as a habitat for certain species otherwise unable to exist.

Restricted access to a limited zone, Eco-district Bottière Chénaie, Nantes (France) - Photo source: Cerema

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Water management and quality > 02-1 Urban water management > 02-2 Flood management regeneration 04| Biodiversity and urban space >04-1 Biodiversity >04-2 Urban space development and regeneration 05| Soil management > 05-1 Soil Management and quality	- Ensuring the quality and availability of potable water resources - Preventing flood - Biologically active area in an inactive area - Preventing plants and animals from anthropogenic pressure - Limiting access to ensure a faster development of a new green space - Increasing soil organic matter
Co-benefits and challenges foreseen	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 03| Air quality issues > 03-1 Air quality at district scale > 03-2 Air quality locally 10| People security 10.2 Control of extraordinary events	- The associated restricted management of vegetation favour vegetation density and then carbon sequestration and urban heat island mitigation - Helping filter air pollutants - Protects urbanised areas against various threats - Reserve for flood events
Possible negative effects	10| People security	When not properly protected, could become sites of undesired activities

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Neighbourhood, district
Impacted scales	District, town/city, region

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	1 to 20 years, depending on the nature of the challenge it is required to answer and the types of plantation the latter needs
Life time	not defined
Management aspects (kind of interventions + intensity)	It requires a low intensity garden/forest/marsh maintenance and protection from access.

II.3 Stakeholders involved	
Technical stakeholders	- Security experts - Natural resources experts and managers - Representatives of various municipal and governmental agencies - Environmental protection experts - Landscape architects - Specialized green spaces management firms, horticulturist and gardeners.
Stakeholders involved in the decision process	- Stakeholders of various governmental bodies - Public service providers - Environmental protection agencies - Municipalities - Security agencies
Social aspects	- Involvement of the residents and NGOs in decision-making - Openness to recommendations by the public

II.4 Design / techniques/ strategy	
Knowledge and how-know involved **Or key points for success**	- Resource management - Water management - Environmental protection - Security management and expertise - Maintenance and protection - Biodiversity
Materials involved	- fences and communication materials

II.5 Legal aspects related
Various and often conflicting fields to be involved, some with classified regulation

II.6 Funding Economical aspects	
Range of cost	Investment: €1-30 / square metre, depending on the nature of the project Maintenance: €0.1 to 4 per square metre annually, depending on the nature of the project
Origin of the funds (public, private, public-private, other)	Usually public

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Solar panels Irrigation systems Water reservoirs Cattle

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	Appropriate location Acceptance of the locals (communication) Appropriate maintenance and protection
Limiting factors	- Institutional constraints - Bad protection and negligence - Vandalism - Bad communication

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Brownfield area Abandoned areas
Close NBS	Large urban public parks Urban public spaces with specific uses Ponds and reservoirs Heritage Gardens Cemetery

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Antrop, M. (2004), Landscape change and the urbanization process in Europe. *Landscape and Urban Planning*, 67(1-4):9-26

Jongman, R.H.G. (2004), European ecological networks and greenways. *Landscape and Urban Planning*, 68(2-3):305-319

Wilderer, P.A. (2004), Applying sustainable water management concepts in rural and urban areas: some thoughts about reasons, means and needs. *Water Science and Technology*, 49 (7):7-16.

Kristoffersen, P. *et al.* (2008), A review of pesticide policies and regulations for urban amenity areas in seven European countries. *Weed Research*, 48: 201–214.

Berg, van den, *et al.* (2007), Preference for Nature in Urbanized Societies: Stress, Restoration, and the Pursuit of Sustainability. *Journal of Social Issues,* 63: 79–96.

Herzele, A. – Wiedermann, T. (2003), A monitoring tool for the provision of accessible and attractive urban green spaces. *Landscape and Urban Planning*, 63(29):109-126.

IV.2 Sources used in this factsheet

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> LIMIT OR PREVENT SOME SPECIFIC USES AND PRACTICES

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS is the use of state regulations or community consensus. Through the implementation of this NBS certain areas can be preserved from intensive utilization or a resource efficient utilization can be emphasized. Master Plans or Local Building Acts define for example the ratio of construction within the building plot – if development is permissible – thus, green areas can be preserved by defining them as land which cannot be developed. Unlike to the NBS "Limit or prevent access to an area" this NBS concentrates on built-up areas of the city and its geographical scope remains within the administrative boundaries of the city.

Different variants existing

Two kinds of limitation / or advancement can be identified from the aspect of the purpose of the regulation:

- the conditions of property build-in, / land use
- the conditions of resource utilization

=> Urban planning master plan /

We can differentiate 3 scales of interventions in this type of NBS:

- City of metropolitan scale, (Development concept, masterplan)
- Neighbourhood scale (action plan)
- Object scale ((Local) Building Code)

On the scale of a development concept or masterplan, the important issue from NBS point of view is to ensure: the preservation of green areas around the boundaries of the city. This is a rather important issue from the point of view of urban climate. However, usually the boundaries of the city also contains abandoned industrial site, wasteland or railway, what makes rather difficult to handle these territories.. Usually after some time, nature would automatically takes force, therefor considering the usage of NBS is a simple, considerably cheap solutions. The only negative effect could be the low social acceptance due to safety reasons – this aspect however can be handled easily too.

Fig. 1: The development concept of the green space system of Budapest
(Source: Budapest 2030 long term urban development concept, 2013)

Fig. 2: Barcelona Trees Master Plan (2016)
(Source: Master plan for Barcelona's Trees 2017-2037)

Prescribing NBS projects within a neighbourhood:

When planning a certain project of a neighbourhood scale, action plan is used. This is a good opportunity to create new green spaces or alleys. See Figure 3 as an example, where the action plan for the rehabilitation of Bramfeld city centre**.**

Fig 3: Bramfeld City Centre, Hamburg - Urban Frame Planning and Action Concept
Source: http://www.duesterhoeft-hh.de/projekte.php?kategorie=Staedtebau&projekt_id=16

On object or plot scale, urban planners have the possibility to prescribe the ratio of greening within the construction plot for the investor. This can be made on a national level by a Building Code. This is the highest level of policies, and it also needs a serious consideration.

On other hand, local authorities have also the possibility to prescribe certain measures. For example the share of green areas in ration to the area built-in, or they might also prescribe the compulsory usage of green roofs on flat roofs. It is also a solution to prescribe the amount of trees that should be planted on the plot in ratio to the area built-in. The latter is the case in France for example.

Hamburg - Source: Gründachstrategie Hamburger Preis für Grüne Bauten, http://www.hamburg.de/gruendach

=> Restriction of resource overutilization

Due to the climate change and overpopulation in the case of severe drought periods of the year water utilization for sprinkling can be restricted.

In dry climate conditions or in severe drought periods the mindful use of fire or the total prohibition of opening fire can be ordered.

Standing in queues in front of a natural spring in Capetown - 2018.

(*Photo: Bloomberg / Getty Images Hungary*)

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban space >04.1 Biodiversity 06| Resource efficiency >06.1 Food, energy, water 07| Public Health and well-being >07.3 Health 10| People security >10.2 Control extraordinary events	- Most of the restrictions of this NBS favour biodiversity - Restricting use of water helps preserving drinkable water resource - Restricting water pumping helps preserving rivers water level - Restricting or forbidding use of pesticides helps preserve health - Built-up ratio controls the ratio of sealed area, thus the effects of stormwater can be mitigated
Co-benefits and challenges foreseen	03| Air quality issues 07| Public Health and well-being >07.2 Quality of life 09| Urban planning and Governance	- Help filter air pollutants - Help enhancing quality of continuity within the city. - Ensuring a better distribution of green spaces in the city - Enhancing access to high quality green spaces for citizens.
Possible negative effects	08| Environmental Justice and Social Cohesion 11| Green Economy	- Social disaffection may arise if the use of certain resources is restricted or prohibited. - If the area of development land is restricted (with a sudden building code) the price of properties might rise in an unpredictable way.

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales	
Scale at which the NBS is implemented	It depends on the scale of regulation. Building Codes can describe general rules country-wide. Master Plans or development concepts usually contain policies for the city or district. The Local Building Act defines rules on building plot bases, but generally, at the neighbourhood scale.
Impacted scales	The scales impacted are the same as listed above: it can be country-wide (Building Code); it can concern a city or district (Master Plan, Development Concept, etc.); or can relate to neighbourhood or object (Action Plan, Local Building Code). On other hand the impact extends beyond the level of implementation, assuming that certain impacts will be aggregated with time.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	These kinds of limitations can be a matter of mid- and long-term regulations, except for action plans that are usually aiming a change in 2-5 years).
Life time	From the time the regulation comes into force in an ascending order until its overruling.
Sustainability and life cycle	As the elements of the network are various, it has a sound fundament and could be sustainable, but due to the alteration of urban plans it is vulnerable. Its lifecycle also varies in great intervals, but if biodiversity has priority it can enlarge to decades.
Management aspects (kind of interventions + intensity)	Depends on the nature of the implementation that needs to be taken into consideration. (E.g.: Green field and brown field investment, construction)

II.3 Stakeholders involved/ social aspects	
Technical stakeholders and network	- urban planners, urban development experts, - developers, investors, constructors - permitting authorities, controlling authorities, - local authorities, and their expert advisors, - experts related to urban management - Owners of properties, concerned by the regulation During the decision-making process lawyers and experts have to work together.
Stakeholders involved in the decision-making process	- related ministries and authorities, - local authorities, - urban planners - Inhabitants, invited to the participatory planning process
Social aspects	Master plans and the restrictions must serve the benefits and interests of the citizens. If awareness rising and environmental education have a sound base, inhabitants can also take part in the decision-making process with responsibility.

II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	To meet the right decisions for a corresponding regulation to the adequate aims set; the state of art must be analysed precisely. During the planning process stakeholder involvement needs to be organized, to achieve a high level of social acceptance of the regulation. If the investors can be convinced that the value of the property will be increased by the high quality NBS implemented in the project.
Materials involved	Building Code, Master Plan, Structure Plan, Local Building Act, Action Plan

II.5 Legal aspects related
The municipality must create regulations which serve the benefits of the green areas and the interests of the community.

II.6 Funding Economical aspects	
Range of cost	The costs for external expertise for masterplan, which can vary by country. The Chief architect's time that is used for negotiations with potential investors.
Origin of the funds (public, private, public-private, other)	Regarding the regulation, it's public.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
The charging of penalty fees. By different kinds of awareness-rising methods the sense of responsibility can be developed in individuals and social groups > Nature Based Education.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Social acceptance
Limiting factors	- Profit oriented approach of private investors

III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- Higher rate of build-up area within the municipality. - Higher values for constructed surface within the plot. - No regulation of such kind in favouring (NBS)
Close NBS	- Urban planning strategies

IV/ References

IV.1 Scientific and more operational references (presented jointly)
Trees for Life – Master Plan Barcelona 2017-2037, 2017, Àrea d’Ecologia Urbana. Ajuntament de Barcelona. Vejre, Henrik & Primdahl, Jørgen & Brandt, J. (2018). The Copenhagen finger plan. Keeping a green space structure by a simple planning metaphor. 310-328. Integrated Water Resources Management: Toolbox - http://www.cawater-info.net/bk/iwrm/toolbox_e.htm
IV.2 Sources used in this factsheet
Trees for Life – Master Plan Barcelona 2017-2037, (2016), Àrea d’Ecologia Urbana. Ajuntament de Barcelona. 2017 Budapest 2030 long term urban development concept, 2013; http://infoszab.budapest.hu:8080/GetSPFile.aspx?Attachment=egyebkozzetetel/Lists/Hirdetmeny/Attachments/74/Budapest_2030.pdf Vejre, Henrik & Primdahl, Jørgen & Brandt, J. (2018). The Copenhagen finger plan. Keeping a green space structure by a simple planning metaphor. 310-328.

V/ Authors

Name	Institution / company	Writer/ reviewer
Flóra Szkordilisz	MUTK	Writer
Marjorie Musy	Cerema	Reviewer

- Urban (green) spaces management
- Urban planning strategies

> ENSURE CONTINUITY WITH ECOLOGICAL NETWORK

> TAKE INTO ACCOUNT THE DISTRIBUTION OF PUBLIC GREEN SPACES THROUGH THE CITY

> PLANNING TOOLS TO CONTROL URBAN EXPANSION

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition

This NBS contains the regulations, which can enable spatial connectivity between green spaces. The regulations make possible the use of different kinds of NBS that should be diverse as much as it can be to ensure the safe connectivity between wide green places. Usually the function of the linear elements of the network is only to give shelter to the fauna. Due to this NBS the biodiversity of the green places can be granted.

Different variants existing

Three kinds can be identified in the aspect of spatial extent:

=> Points or stepping stones (private gardens)

Private garden, Hungary *(Source:* https://index.hu/urbanista/2016/10/05/mihalyfi_erno_termeszetvedelmi_kertje_a_rozsadombon/*)*

Private garden, Hungary *(Source:* http://www.pronaturakert.hu/kertepites*)*

=> Linear (river banks, green ways, street tree line)

© Riverbanks, Jászberény, Hungary *(Source: Németh László* http://www.panadea.com/hu/utazasi-kalauz-utikonyv/europa/magyarorszag/eszak-alfold/jaszbereny/fotogaleria/gal-003,*)*

Basel, Switzerland, complex greenway *(Source:* http://citytransport.info/Lawn.htm*)*

Street tree line, San Fransisco *(Source:* https://nacto.org/publication/urban-street-design-guide/intersection-design-elements/visibility-sight-distance/*)*

=> Patches (public green areas, parks)

Berlin, Germany *(Source:* https://www.gapyear.com/articles/travel-ideas/going-green-in-berlin*)*

Dublin, Ireland *(Source:* https://en.wikipedia.org/wiki/Urban_park*)*

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	04| Biodiversity and urban spaces >04-1 Biodiversity >04-2 Urban space development and regeneration 09| Urban planning and Governance > 09-1 Urban planning and forms > 09-2 Urban planning and governance	- Provide a habitat for small mammals, birds and insects - Favour species diversity - Favour green spaces diversity - Integration in city, offering diversity of space and connecting them - Implying different stakeholders and their connection
Co-benefits and challenges foreseen	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 02| Water management and quality > 02-1 Urban water management > 02-2 Flood management 03| Air quality issues > 03-1 Air quality at district scale > 03-2 Air quality locally 05| Soil management > 05-1 Soil Management and quality 07| Public Health and well-being > 07-2Quality of life 08| Environmental justice and social cohesion 08-1 Environmental justice	- Contribute to carbon sequestration - Shade passways and roads, contribute to urban heat island mitigation - Different components of the continuity contribute to stormwater infiltration - Help filter air pollutants - Aesthetic value - Reducing the erosion caused by water run-off, increase in soil organic matter - Support for education - Contact with nature
Possible negative effects	07 Public Health and well-being	- Presence of undesired insects and allergens

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales	
Scale at which the NBS is implemented	From the considered space to the whole city, by connecting the separated or segmented green patches, lines and nodes.
Impacted scales	For most urban challenges, the impacted scales are limited to the object scale. However, concerning biodiversity, due to the created network, the impacted scale is much larger. The complete network of this kind of intervention can also influence the climate of the city and the well-being of inhabitants.

II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	0,5-15 years => linked with the growth of plants It requires much time in the case of trees, but in the case of herbaceous layer less than a year would be enough.
Life time	It depends on the plant species: - More than 100 years for some species, when they are well managed, for example: indigenous, slow growing tree species. - Some plants need to be replaced after 4-6 years (herbaceous). Indeed, after some years scattering seeds is required to refresh the genome. - In the case of annual plants, the plantation should be done in a well determined sequence, thus the nutrition content of the soil will not have depleted and pests could not come forth.
Sustainability and life cycle	As the elements of the network are various, it has a sound fundament and could be sustainable for a long time, but due to the alteration of urban plans it is vulnerable. Its lifecycle also varies in great intervals, but if biodiversity has priority it can enlarge to decades.
Management aspects (kind of interventions + intensity)	- No or limited irrigation - Pruning (to avoid accidents and the damage of electricity lines) - 1-3 interventions per year, it depends on the vegetation type - Less or no sensitive to frost in comparison with other segregated plants

II.3 Stakeholders involved/ social aspects	
Technical stakeholders and networks	- Landscape architects - Specialized green spaces management firms, horticulturist and gardeners. - Nature conservation engineers Each stage requires special experts and their joint work from planning to execution.
Stakeholders involved in the decision process	- Owners, co-owners (in case of a joint ownership property) - NGO's - Residential community - Municipality
Social aspects	-Necessity to find an agreement with all the co-owner of an area=> importance of the participatory process. -Green solutions are popular in the participative processes - Communities can be involved into the decision-making process

II.4 Design / techniques/ strategy	
Knowledge and know-how involved Or key points for success	- Selection of plant adapted to: • the local climate • challenges targeted • local soil conditions • the traffic intensity (the level of pollution) - Knowledge of the impact on biodiversity of each node, global overview of the network
Materials involved	All types of indigenous plants

II.5 Legal aspects related

Creating and maintaining a continuous ecological network across the city, the municipality has to incorporate it into the master plan.

II.6 Funding Economical aspects	
Range of cost	Investment: It depends on the type of places where the elements of the eco network will be planted. Maintenance: If the network is properly set the maintenance fees should be quite low due to its vitality and diversity. Only annual or seasonal pruning and mowing tasks should be applied.

Origin of the funds (public, private, public-private, other)	- NGO's or residential community - Municipalities (or the company owned by the municipality) plant vegetation on its administrative areas: streets and open public places. - They can and should work together effectively.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
Conventional green parks, semi intensive gardens, like English gardens are also can be part of this NBS, as animals, living in urban area, have a wide tolerance against human activities and heavy disturbance. Abandoned industrial areas, partially renovated or reutilized can be a perfect place for hideout. Balcony flowers and balcony gardens can be aesthetic elements and join the buildings into the ecological network. Complementary grey elements as wildlife crossing (squirrels bridges, tunnels, …).

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Higher level of biodiversity, complex defence against diseases - Maintenance of green spaces - Particular attention to the private spaces (garden)
Limiting factors	- Difficulties of management (Special knowledge is required to plan and maintain fine ecologically sound environment). - Governance and authorizations: changing in masterplan, private owners may change the utilization of their properties. - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Wildlife tunnels and bridges target fauna biodiversity, sometimes efficiently.
Close NBS	• Reopened streams • Remeander rivers • Choice of plants • Parks and gardens • Insect hotels • Beehives • Vegetation engineering systems for riverbanks erosion control • Distribution of green space Ensuring continuity with ecological network is a complex task, numerous types of NBS's can be applied, but the principle is to increase or maintain the diversity.

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Haifeng Li, Wenbo Chen, Wei He, (2015) *Planning of Green Space Ecological Network in Urban Areas: An Example of Nanchang, China*, doi:10.3390/ijerph121012889

Maria Ignatieva, Glenn H. Stewart, Colin Meurk, (2010) *Planning and design of ecological networks in urban areas*, doi: 10.1007/s11355-010-0143-y

JiaxingWei, Jing Qian, Yu Tao, Feng Hu and Weixin Ou (2018) *Evaluating Spatial Priority of Urban Green Infrastructure for Urban Sustainability in Areas of Rapid Urbanization: A Case Study of Pukou in China*, Sustainability 2018, 10, 327; doi:10.3390/su10020327

IV.2 Sources used in this factsheet

LENZHOLZER Sanda, 2015, *Weather in the city – How design shapes the urban climate*, naio10 publishers, 224 pages.

V/ Authors

Name	Institution / company	Writer/ reviewer
Barnabás Körmöndi	**MUTK**	**Writer**
Marjorie Musy	Cerema	Reviewer

> TAKING INTO ACCOUNT THE DISTRIBUTION OF PUBLIC GREEN SPACES THROUGH THE CITY

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	This NBS is usually implemented into the masterplan of a city, where several factors should be considered, like urban structure, mobility network, neighbourhoods with different functions, infrastructure network, needs of inhabitants and connectivity. In optimal cases, the green public places can be reached in 5-10 walking minutes by each dweller. The optimal distribution of green spaces can be defined in an urban development concept, master plan or structure plan. Depending on the genre of plan the scale might vary. It can have different and complementary aims: offer quickly accessible green spaces to each dweller for daily recreation and having a well distributed vegetation so that to mitigate urban heat island effect at city scale.

Different variants existing

<u>3 different types can be identified from the aspect of city typology:</u>

a) historical cities and where greenbelt could be developed along the city walls
b) modern, developing city
c) shaped by the geographical conditions

a) The green area structures in Helsinki
(Sources: https://fluswikien.hfwu.de)

b) Barcelona Trees Master Plan (2016)
(Source: Master plan for Barcelona's Trees 2017-2037)

c) Copenhagen, Denmark shaped by geographical conditions
(Source: Vejre Henrik, 2018)

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-2 Climate adaptation 03| Air quality issues > 03-1 Air quality at district scale 07| Public Health and well-being > 07-1 Acoustics > 07-2 Quality of life 09| Urban planning and Governance > 09-1 Urban planning and forms > 09-2 Urban planning and governance	- Reduce the urban heat island effect - Improve microclimate - Help filter air pollutants - Noise/Acoustic buffer - Help stress release and human well-being, network for sport practise - Covering the entire city with easily accessible green places - Integration of green spaces in city, offering diversity of space and connecting them - Implying different stakeholders and their connection
Co-benefits and challenges foreseen	04| Biodiversity and urban spaces >04-1 Biodiversity 05| Soil management > 05-2 Soil Management and quality	- Provide habitats for small mammals, birds and insects. - Urban soils self-regeneration can take place as the proportion of the unsealed surfaces increase
Possible negative effects Possible negative effects	10| People security 07| Public Health and well-being	- More spaces to hide - Presence of undesired insects and allergens

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales	
Scale at which the NBS is implemented	The implementation concerns the neighbourhood or district, but eventually covers the entire city to have an overview. Scale might vary according to the plan. However, typically the entire city is affected by the regulation.
Impacted scales	The scales impacted are in most of the cases the whole city. In each district the public green places should be reached in a specified time interval, thus in an optimal case good-quality public green places (appropriate for recreation) can be reached in 5-10 walk minutes by each dweller.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	2-4 years => linked with the growth of plants It could be a bit longer that other types of vertical structures to cover the top of the surface, because in this case plants start from the soil level.
Life time	It depends on the time-frame of the plan and plant species: - More than 30 years for some species, when they are well managed. For example, Wisteria plant. - Some plants need to be replaced after 4-6 years. Indeed, after many years, they develop senescence aspects. Oldest stems become lignified and do not carry leaves any more. In case the wall needs to be renovated, plants must be completely or partly removed.
Sustainability and life cycle	As the elements of the network are various, it has a sound fundament and could be sustainable for a long time, but due to the alteration of urban plans it is vulnerable. Its lifecycle also varies in great intervals, but if biodiversity has priority it can enlarge to decades.
Management aspects (kind of interventions + intensity)	- No or limited irrigation - Pruning (to keep clear around openings and to prevent plants from gaining the roof and gutters) - 1-3 interventions per year

II.3 Stakeholders involved/ social aspects

Technical stakeholders and networks	- Urban planners, local authorities and related experts (e.g.: mobility, infrastructure) - Landscape architects - Specialized green spaces management firms, horticulturist and gardeners. - Maintenance company for the green spaces The joint work of different type of experts is required during the planning, through decision-making process until the execution and maintenance.
Stakeholders involved in the decision process	Municipality Regional authority (depending on the planning structure of each country)
Social aspects	- Necessity to find an agreement with potential investors of an area=> importance of the participatory process. - Green solutions are popular in the participative processes - Communities can be involved into the decision-making process

II.4 Design / techniques/ strategy

Knowledge and Know-how involved Or key points for success	- Urban planning methodology, - Urban climate research methods - Sociological studies - Civil engineering
Materials involved	- Information about the current status of land use (satellite imaginary) - Measuring urban climate - Questionnaires for the dwellers

II.5 Legal aspects related

The municipality has to accept the masterplan, which has to be in accordance with the national legislation of urban planning and construction requirements.

II.6 Funding Economical aspects

Range of cost	Costs of planning, implementation and maintenance
Origin of the funds (public, private, public-private, other)	The implementation of the masterplan is budgeted by the municipality.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)

When particular urban planning process has taken place, the functions of each district are going to be decided by considering its spatial benefits. The distribution of urban green spaces within each district is set according to the function of that area. Topographical or geographical features can spoil the ideal plan, but in most cases, natural elements can be the backbone of the newly developed green infrastructure.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Governance implying all the stakeholders - Possibility to change function of spaces and to re-nature them - Participation opportunity for local stakeholders
Limiting factors	- Cost of the maintenance of green areas - Urban density and land pressure - Use, management or property conflicts - Vandalism
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	- No existing plan in favouring NBS or green infrastructure. - Artificial grass in the case of sport centres.
Close NBS	Ensure continuity of ecological networks

IV/ References

IV.1 Scientific and more operational references (presented jointly)

Dr. Amira Mersal (2016) *Sustainable Urban Futures: Environmental Planning For Sustainable Urban* Development, Procedia Environmental Science 34 (2016) 49-61

Dr. Amira Mersal (2017) *Eco City – Challenge and opportunities in transferring a city into green city,* Procedia Environmental Science 37 (2017) 22-33

Pascale Joassart-Marcelli, Jennifer Wolch & Zia Salim (2011) *Building the Healthy City: The Role of Nonprofits in Creating Active Urban Parks*, Urban Geography, 32:5, 682-711,

Sotoudehnia F, Comber A (2010) *Poverty and environmental justice: a GIS analysis of urban greenspace accessibility for different economic groups*. In: 13th AGILE Int Conf on Geographic Information Science, Guimaraes, Portugal, 10–14 May 2010

World Cities report 2016 – Chapter 2, 5, 7.

Trees for Life – Master Plan Barcelona 2017-2037, (2016), Àrea d'Ecologia Urbana. Ajuntament de Barcelona. 2017

Vejre, Henrik & Primdahl, Jørgen & Brandt, J. (2018). *The Copenhagen finger plan. Keeping a green space structure by a simple planning metaphor*. 310-328.

Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (eds., 2017). *Urban Green Infrastructure Planning: A Guide for Practitioners.* GREEN SURGE. Retrieved from http://greensurge.eu/working-packages/wp5/

IV.2 Sources used in this factsheet

Vejre, Henrik & Primdahl, Jørgen & Brandt, J. (2018). The Copenhagen finger plan. Keeping a green space structure by a simple planning metaphor. 310-328.

V/ Authors

Name	Institution / company	Writer/ reviewer
Barnabás Körmöndi	MUTK	Writer
Marjorie Musy	Cerema	Reviewer

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	The traditional-continental land use plans and both the integrated development strategies have certain tools to tackle urban expansion. These tools form a framework of different, but harmonized measures. Among these measures, some of them contribute to ensure the implementation of NBSs.

Different variants existing

The planning tools to control the urban expansion have two main types: the direct and the indirect tools. The direct measures are mostly strong regulations limiting and/or prohibiting building on the greenfield at the city limits. The indirect tools represent an integrated approach towards the issue, using measures concentrating developments to other parts of the cities, thus preserving the greenfield.

=> Direct planning tools: The direct tools used often are

(1) **land use plan:** the strong land use regulation in the local plans (in the continental countries);

(2) **regional regulations:** high level decision-making bodies ensure certain changes within a region by a particular policy (e.g. in the case of Budapest Agglomeration or the Balaton Recreational Region in Hungary the Hungarian Parliament will decide);

(3) **permitting process (planning board):** the agricultural or environmental authorities will regulate the targeted change of land use by involving sectoral professionals into the planning of local development strategies.

Detail of the regulation plan of Balatonlelle, Hungary

(Source: www.balatonlelle.hu)

Detail of the Regulation Plan of the Balaton Region, Hungary

(Source: https://net.jogtar.hu/)

Coordination meeting at the planning of industrial park in Nyíregyháza, Hungary

(Source: www.nyiregyhaza.hu)

=> Indirect planning tools: The indirect tools do not come into force, but they are implemented together with other policies and measures. The main types of this planning approach are

(1) brownfield regeneration programs which attract young families and investors of workplaces in the inner city districts,

(2) favouring the decentralisation by focusing the developments of sites in the proximity of railway stations and joining them to the existing build-up area of city,

(3) compact developments of the city by planning the adequate capacities in public transportation of the periurban areas.

Green courtyard with playground at the Ferencváros regeneration area Budapest, Hungary (Source: https://ingatlan.com/)

New housing estate near to the railway station at town Piliscsaba, Budapest Agglomeration Hungary (Source: www.eloepiteszet.hu)

Green tracks in Brussels (Source: http://citytransport.info)

I.2 Urban challenges and sub-challenges related + impacts

Main challenges and sub-challenges targeted by the NBS	01| Climate issues > 01-1 Climate mitigation > 01-2 Climate adaptation 03| Air quality issues > 03-1 Air quality at district/city scale 07| Public Health and well-being 07-1> Acoustic 07-2> Quality of life 07-1> Health 09| Urban planning and governance > 09-1 Urban planning and form > 09-2 Governance in planning	- A more compact city (a city with shorter distances) permits to reduce greenhouse gas emission due to transportation and low density and to favour carbon sequestration in freed soil and associated vegetation - Combining density and more green surfaces, is an issue to mitigate urban heat island - A better organised transportation network leads to less traffic, less air pollution, less noise, less travel time, and globally to improve quality of life and health. - Better urban finances - More effective planning
Co-benefits and challenges foreseen	04| Biodiversity and urban space >04-2 Urban space development and regeneration 05| Soil management >05-1 Soil management and quality 08| Environmental justice and social cohesion > 08-1 Environmental justice	- Ensures the protection of open and green spaces and their connectivity - Supporting short distance transportation of agricultural goods within the agglomerations - Preserving organic soil - Ensuring the equal development of high-quality NBS within the city
Possible negative effects		Higher real estate prices in the city

II/ More detailed information on the NBS entity

II.1 Description and implementation at different spatial scales

Scale at which the NBS is implemented	The planning tools can be used on a neighbourhood, city, or regional level
Impacted scales	The range of scales impacted is very wide: this NBS can influence the object, neighbourhood, city and regional planning levels too.

II.2 Temporal perspective (including management issues)

Expected time for the NBS to become fully effective after its implementation	Resulting from the character of urban planning, the expected time to become fully effective varies: from 0 to 5 years => depends on the development needs of the given area, and also depends on any parallel developments, which influence the development willingness in the area, or in the city/region. It also depends on the process used to elaborate plans, which can be longer if people participation is needed.

Lifetime	The lifetime of the planning is strongly linked to the political and public acceptance of the used tools. If the use of the tool meets the needs and demands of the public, the political acceptance is normally high, so the lifetime of the NBS is relatively long (10-50 years). If the used tool – mainly in the case of direct tools – does not meet the public interest and needs, and the local/regional society formulates unacceptable interests, the political support of the used solutions will be low, so the lifetime of the NBS will be short.
Sustainability and life cycle	The sustainability and life cycle of the planning is related to its result sustainability, and as a consequence of the used NBS. It depends on its success and on the current on-going social process and changes. The life cycle of the land use plans in the continental planning systems is usually legally 10 years, and in this period a full or partial revision is taking place. These revisions should provide an opportunity for the planning authorities to revise or to keep the used tools at normal way, without causing any political conflicts. Normally it is a modification opportunity outside the regular full review of the plans and regulations, but practically they are politically biased, so in many countries it is more an exception than a regular solution.
Management aspects (kind of interventions + intensity)	The direct tools are mostly administrative measures that are relatively cost-effective, but their sustainability depends on the actual political willingness, so they can be easily modified. The indirect tools are mostly greater development actions that need not only administrative measures, but expensive investments, and large multi-actor processes too. So, they are more complicated tools, require more management capacities and involve long complex processes, but their sustainability is greater, and the modification needs too more capacities and energies.

II.3 Stakeholders involved / social aspects

Stakeholders involved in the decision process	- Local authorities, regional governments, authorities, state agencies, landowners, co-owners, tenants, local and regional NGOs, agricultural and forest entrepreneurs, cooperatives, chambers, property developers, investors, banks
Technical stakeholders & networks	- Regional and urban planners - Landscape architects - Specialized green belt authorities and companies - Property managers
Social aspects	-The use of NBS has a positive impact on the wider community because of its environmental benefits and shorter travel time, in the indirect cases the better services, living conditions in the city and surroundings. - The NBS is usually received unfavourably by the housing and trade sectors who would benefit from the possible greenfield developments. Furthermore, the smaller amount of available housing lots will raise the property prices in the housing sector.

II.4 Design / techniques/ strategy

Knowledge and know-how involved	- The implementation of NBS needs, in both – direct or indirect – forms, high skills and experience in urban and regional planning, and mostly landscape architecture too. - The indirect solutions need more knowledge to implement the other measures in the city, what help to control the urban expansion.
Materials involved	Not relevant in this NBS.

II.5 Legal aspects related

The urban and regional planning processes and techniques are regulated by the law in the European countries. In some post-socialist countries, the regional land use plans are legal documents, in the form of act.

II.6 Funding Economical aspects

Range of cost	- The planning processes are mostly inexpensive tools compared to the cost of their implementation (construction), but for a municipality, they are time consuming.
Origin of the funds (public, private,	- State or local municipal budget, some cases with the support of

public-private, other)	private companies, in form of contract with the competent authorities.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
The use of direct version needs the coordinated planning with other documents of the city, or the county, the smaller or greater region. The use of the indirect methods may be combined with an unlimited number of other actions. Both are usually included in the planning toolkit.

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Available potential project sites in the inner city parts - Financial systems (e.g. taxes, or national support policies) supporting the housing developments in the city core - Acceptance from population and all stakeholders
Limiting factors	- Political problems - Legal circumstances - Lack of communication, participation
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	Because this NBS is only an approach in the local or regional planning processes, there may be contradictions with the existing plans
Close NBS	- Take into account the distribution of public green spaces through the city Ensure continuity with ecological network Limit or prevent access to an area

IV/ References

IV.1 Scientific and more operational references (presented jointly)
Act XXI of 1996 on Regional development and Regional Planning Budapest Agglomeration Urban Development Plan, 2014 Comparative analysis of the planning system of seven European countries (working paper of the SPECIAL/IEE project), 2014
IV.2 Sources used in this factsheet
Budapest Agglomeration Urban Development Plan, 2014 Lake Balaton Touristic Region Development Plan 2012 www.nyiregyhaza.hu, 23 February, 2018.

V/ Author(s)

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- **Urban (green) spaces management**
- **Monitoring**

> **BIO-INDICATORS**

I/ General description and characterization of the NBS entity

I.1 Definition and different variants existing

Definition	Bio-indicators are operational tools based on the use of sentinel organisms. Bio-indicators may be a cell, a biochemical process, a living organism, or a community of different organisms. Bio-indicators give information for monitoring and assessing the biological and ecological quality, or the pollution for different environments (air, water masses, and soils).

Different variants existing

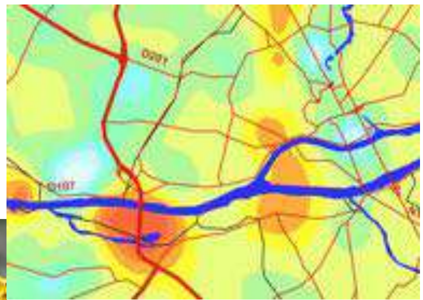
Although the principle is exactly the same for all bio-indicators, we can divide this NBS family into three categories depending on the environment the bio-indicator assesses (air, water, soil) :

=> Air

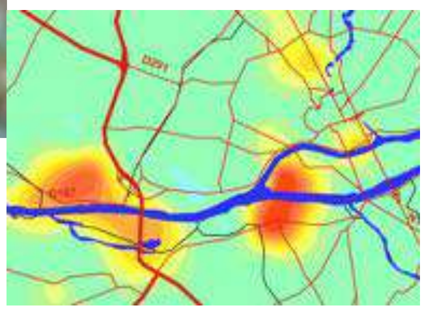
Communities of organisms – for example lichens – are used to assess in an integrative way, targeted pollutions, or a global air quality indication.

Lichen *Flavoparmelia caperata* © J.L. Farou

Lichen *Xanthoria parietina* a NOx marker © J.L. Farou



Example of an “acidity” isopollution map © J.L. Farou



Example of an “ammonia” isopollution map © J.L. Farou

=> Water
For water masses (rivers, standing waters), bio-indicators are based on living organisms communities as invertebrates, fishes, aquatic plants, macrophytes. Communities may be assessed individually (ex. Invertebrates), or grouped in a global and integrative indicator.

Examples : I2M2 (macroinvertebrate-based multimetric index), IBMR (macrophytic biological indicator for river)

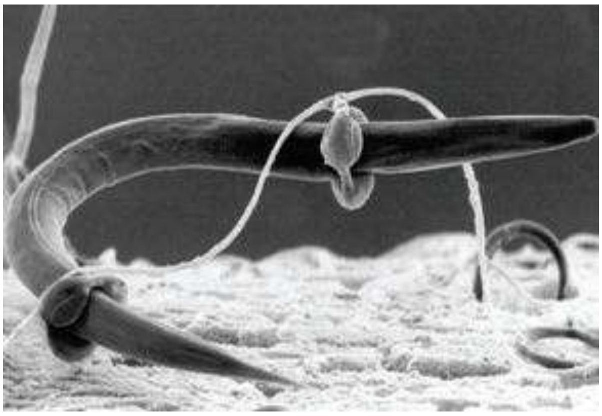
© Aquabio-J.C. Labat

© Aquabio-J.C. Labat

=> Soils
They assess (1) the ecological and biological quality of soils and/or (2) the transfers and effects of contaminants to terrestrial trophic chains.

Examples: earthworms, nematodes communities, plants communities, snails, Omega 3 (lipidic bio-indicator).

Snails exposed in a brownfield
© Université de Franche-Comté



Nematode © in "Soil biodiversity atlas" book- European Commission

Earthworm © in "Soil biodiversity atlas" book- European Commission

I.2 Urban challenges and sub-challenges related + impacts		
Main challenges and sub-challenges targeted by the NBS	02| Urban water management and quality >02.1 Urban water management 03| Air quality >03.1 Air quality at district/city scale 04| Urban space and Biodiversity >04.3 Urban space development and regeneration 05| Soil management >05.1 Soil management and quality	- Bio-indicators help to make a decision in water management, air or soil quality - They help to improve space management
Co-benefits and challenges foreseen	04| Urban space and Biodiversity >04.1 Biodiversity 07| Public health and well-being >07.3 Health 11| Green economy >11.2 Bioeconomy activities	- Help in increasing NBS performance and services : pure water, biodiversity - Help to assess and detect pollution cases - Provide new markets and jobs
Possible negative effects	No possible negative effect noticed	

II/ More detailed information on the NBS entity

II.1 Description and implication at different spatial scales	
Scale at which the NBS is implemented	Bio-indicators may be used at various scales from one spot (a portion of river, a pond, a parcel in a field), to a territory cartography (city, metropolis, drainage/river basin, regional).
Impacted scales	The scale impacted is the scale surveyed, from the spot to a larger territory.
II.2 Temporal perspective (including management issues)	
Expected time for the NBS to become fully effective after its implementation	For operational bio-indicators, from several days to 5-6 weeks depending on the living organisms, how complex the indicator is, and the need for interpretation or not from the collected field data.
Life time	The information given by a bio-indicator is a snapshot at one time. The lifetime may be very short. The validity of the measure ends as soon as the conditions change. Nevertheless, a proper monitoring may implement sequential measures every year or every 5 or 10 years depending on the cases.
Sustainability and life cycle	Bio-indicators give information. They are not a objects. Their implementation uses very few inputs and do not induce any impact on the environments. Only observations or/and very small samples Cost may be a barrier in a long-term implementation and monitoring if funds are limited.
Management aspects (kind of interventions + intensity)	- Observation or sample by an expert or technician (depending on the need to recognize living organism on field or not) - Expert evaluation in recognizing living organisms, performing the interpretation, summarizing and reporting the results and advices.

II.3 Stakeholders involved/ social aspects

Stakeholders involved in the decision process	- Public authorities in charge of environmental policies and control - The manager of the spot or territory to survey (the contracting authority or the delegated operator)
Technical stakeholders & networks	- The manager of the spot or territory to survey (the contracting authority or the delegated operator) - Experts in ecology, living organisms, bio-indicators as a service providers, firms - Experts as scientists and firms, in case of research and development - Public authorities in charge of environmental policies and control.
Social aspects	-The very high level of expert evaluation implies a good communication and governance among the stakeholders

II.4 Design / techniques/ strategy

Knowledge and how-know involved	- High level of knowledge and expert evaluation in: • Living organisms (recognition and taxonomy) • Ecology and specific environments (functional ecology aspects) • Interpreting and connecting the results to an operational and practical answer - Ability to explain, simplify, summarize the methodology and the results - Ability to provide advices from the results and data collected - Ability to update and improve the approach during time (choose updated bio-indicators since they are constantly in development).
Materials involved	- Sampling material - Laboratory materials with many different modalities - Computer, software and data bases.

II.5 Legal aspects related

=> Air

No regulation demands the use of bio-indicators for air. This is a voluntary approach.
Beside, many bio-indicators methodologies are under normalisation process, and currently evaluation or surveyed by the EU and many states.

=> Water

	Rivers			Lake (> 50 ha)		
	2010-2015	**2016-2021**	**2022-2027**	**2010-2015**	**2016-2021**	**2022-2027**
Phytoplancton				IPL	IPLAC	IPLAC
Phytobenthos	IBD2007	IBD2007 reviewed	IBD2007 reviewed			IBD_PE
Macrophytes		IBMR DCE	IBMR DCE		IBML	IBML
Invertebrates	IBGN	IBGN	I2M2		IIL	IMAIL
Fishes	IPR	IPR	IPR+		ILL	ILL

Bio-indicators of population compatible or with evaluation in progress for the EU Water Framework Directive (French acronyms for the indicators). © Les cahiers de l'eau du réseau des CPIE, n°12 déc. 2015

For lakes with a surface under 50 ha, indicators exist and may be used in a voluntary way (not demanded in WFD).

=> Soils

No regulation demands the use of bioindicators for soils. This is a voluntary approach.
Beside, many bioindicators methodologies are under normalisation process, and currently evaluation or surveyed by the EU and many states.

II.6 Funding Economical aspects	
Range of cost	The range of cost is very wide, reaching from: - a one sample analysis (i.e. soil nematodes communities bio-indicator), by around 150 euros - to a complete survey on a territory or cartography associated many samples, analysis and interpretation time (i.e. a river portion water quality survey, a metropolis air quality map), thousands of euros.
Origin of the funds (public, private, public-private, other)	Most of the time the user has to pay the total cost. Subsidies are rare or do not exist for air and soil analysis. For water, public authorities, drainage/river basin agency (specific to France) may subsidy. The research and development of the bio-indicators tools are usually granted at regional, national or European scales.

II.7 Possible combinations with other kinds of solutions (other environmental friendly solutions or conventional ones)
- Combination with physical and chemistry analysis - This NBS can be combined with other NBS (or grey/classical solution related) to assess, monitor and/or control their performance (water plants, wetlands, ecological restoration, soil construction…)

III/ Key elements and comparison with alternative solutions

III.1 Success and limiting factors	
Success factors	- Expertise and specific skills for the operator or the service provider - Availability of a data interpretation reference - Robustness and ease in using the indicator (understand and translate the results into operational decisions/acts) - Plan an action and the assessment on several years for most of the use cases
Limiting factors	- Consent to pay surveys and analyses a bit more expensive than conventional physicochemical analyses (for a greater benefit)
III.2 Comparison with alternative solutions	
Grey or conventional solutions counterpart	No grey or conventional solution, except if conventional physicochemical analyses may be one. Nevertheless, this type of analyse offers a different and weaker frame of information and services.
Close NBS	No close NBS. Nevertheless, bio-indicators are related to several NBS by the fact they allow to assess the performance and the state or level of ecological quality (air, water, soil). For example, bio-indicators make possible to monitor the ecological state and performance of a wetland in purifying water.

V/ References

IV.1 Scientific and more operational references (presented jointly)

EUROPEAN COMMUNITIES, 2000. *Directive 2000/60/EC of the European Parliament and of the council of 23 October 2000 establishing a framework for Community action in the field of water policy*. 2000/60/EC, 72p.

FELD *et al*., 2010. *Indicators for biodiversity and ecosystem services: towards an improved framework for ecosystems*, Biodivers Conserv (2010) 19:2895–2919

LABAT F., 2017. *A new method to estimate aquatic invertebrate diversity in French shallow lakes and ponds*. Ecological Indicators, 81, p. 401-408.

PULLEMAN M. *et al*., 2012. *Soil biodiversity, biological indicators and soil ecosystem services—an overview of European approaches*, Current Opinion in Environmental Sustainability, 4: 529-538.

Réseau des CPIE, 2015, Les cahiers de l'eau du réseau des CPIE, n°12 déc. 2015

Reyjol Y., Spyratos V. & Basilico L., 2013. *Bioindication : des outils pour évaluer l'état écologique des milieux aquatiques Perspectives en vue du 2 e cycle DCE. Eaux de surface continentales.* , 58p.

IV.2 Sources used in this factsheet

ADEME, 2012. Bioindicateurs : des outils biologiques pour des sols durables. Fiches outils, 17 p.

http://www.ademe.fr/bioindicateurs-outils-biologiques-sols-durables-fiches-outils [visited the 15th of March 2018]

ADEME, 2012. Bioindicateurs : des outils biologiques pour des sols durables. Website.

https://ecobiosoil.univ-rennes1.fr/ADEME-Bioindicateur/ [visited the 15th of March 2018]

LESCUYER Thibault, 2017. *Bioindicateurs. Des outils sentinelle pour la qualité de l'eau et des sols*. TSM, Vol. 12, ASTEE ed., pages 3-7.

FAROU, J.L., 2015. Les lichens, indicateurs environnementaux. 9 p. Factsheet on the Plante & Cité website https://www.plante-et-cite.fr/data/fichiers_ressources/fiche_mise_en_page.pdf [visited the 15th of March 2018]

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