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Deliverable 3.2: Report on the relationship between functional traits and ecosystem services of urban vegetation: Inventory and recommendations

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Table of content

Résumé de la démarche

Ce livrable s'intéresse aux Solutions Fondées sur la Nature (SFN) dans le cadre d'une approche d'ingénierie écologique. Il a pour objectif d'une part de faire le lien entre les traits fonctionnels des espèces végétales mises en œuvre dans les SFN, et les fonctions et services éco-systémiques qu'elles peuvent prodiguer. Sur la base d'une revue de la littérature et d'entretiens, les espèces les plus couramment utilisées ont été listées et caractérisées à l'aide de leurs traits fonctionnels. Afin d'optimiser les services éco-systémiques auxquels s'intéresse le projet EVNATURB (gestion des eaux pluviales, atténuation des îlots de chaleur, préservation de la biodiversité), les traits favorisant ces services ont été mis en avant.

Dans un second temps, ce travail s'interroge sur les conséquences des changements globaux sur cette nature en ville, sur l'évolution de ses traits fonctionnels et sur ses conséquences en termes de durabilité tant des espèces que des services éco-systémiques qu'elle peut rendre.

Enfin, le livrable se conclut par des recommandations en termes d'espèces et de pratiques pour s'assurer de la durabilité de ces solutions dans le temps dans un tel contexte.

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Summary

This deliverable focuses on Nature-Based Solutions (NBS) within the framework of an ecological engineering approach. It aims on the one hand to make the link between the functional traits of plant species implemented in NBS, and the ecosystem functions and services that they can provide. Based on a literature review and some interviews, the most commonly used species were listed and characterized using their functional traits. In order to optimize the ecosystem services in which the EVNATURB project is interested (rainwater management, mitigation of heat islands, preservation of biodiversity), the features favoring these services have been highlighted.

Secondly, this work questions the consequences of global changes on this nature in the city, on the evolution of its functional traits and on its consequences in terms of sustainability of both species and the ecosystem services it provides.

Finally, the deliverable concludes with recommendations in terms of species and practices to ensure the sustainability of these solutions over time in such a context.

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1. Introduction

In the urban environment, Nature-Based Solutions (NBS) can take various forms (Dorst et al., 2019) such as urban forests (Tomao et al., 2017; Yao, Zhao, & Escobedo, 2017), green roofs and facades (Xing et al., 2017; Frantzeskaki, 2019), parks and street trees (Santiago Fink, 2016; Giannakis et al., 2016), ecological corridors (Giannakis et al., 2016), ponds, natural water retention areas or vegetated swales (Scott et al., 2016; Xing et al., 2017), pervious pavements (Fini et al., 2017), urban gardens (Cabral et al., 2017; Van der Jagt et al., 2017) including rain gardens (Scott et al., 2016), or urban agriculture (Artmann & Sartison, 2018).

The integration of such NBS in cities, in a context of global change, raises many questions on the species that are usually used, the way they are managed and on the practices that are used for their maintenance. Consequently, practices vary accordingly: human interventions on a site can range from very limited modifications to major ones, such as the creation of ecosystems (Gómez Martín et al., 2020). NBS requiring greater management efforts are usually implemented in the downtown areas of cities, while in the peripheries, NBS that require less management are often present (Krauze & Wagner, 2019).

This deliverable aims to address these questions and attempts to provide some recommendations for a sustainable implementation of urban NBS. After a first section introducing the main ecological properties of NBS, the second one present the current species and management practices implementing in cities. Based on this analysis, the third section focus on the ways to overcome the disruptions due to global change and their consequences. The rationale behind this approach is to provide a detailed representation of NBS challenges and potential solutions to ensure the continuity of these solutions in the cities of tomorrow.

2. NBS properties: the functional traits behind the ecosystem services

The urban forms of NBS mentioned above are often aimed at flood prevention, urban heat islands mitigation, biodiversity conservation, etc. (Frantzeskaki, 2019; Hobbie & Grimm, 2020). Today, NBS are being used as tool for local adaptation and for immediate results, as part of pragmatic responses to manage emergencies. They are a direct answer to climate change and landscape fragmentation as they restore biomass in the city. The benefits they provide, such as flood prevention or heat control, are called **ecosystem services**. Ecosystem services are usually classified into four main categories: supporting (providing habitats for species, and maintaining genetic diversity), provisioning (provision of food, freshwater and raw material), regulating (air filtering, microclimate regulation, noise reduction, and water drainage/filtering) and cultural services (physical- mental health and recreation). These services are of particular interest in urban environments (Bolund & Hunhammar, 1999, Maas et al., 2006; Tzoulas et al., 2007).

Ecosystem services (an anthropocentric concept) can be seen as the result of **ecological functions** (a concept centred on ecosystems and their components) provided by living beings. An ecological function is best described by the interaction of species or through their ecological role where a species or group of species maintain a biogeochemical flux or pool, and/or support ecosystem productivity (Brodie et al., 2018).

In turn, these functions are influenced by individual characteristics often referred to as functional traits. A **functional trait** is a morphological, physiological or phenological characteristic of an organism measured at the level of individuals and which affects its individual performance (Violle et al., 2007).

For instance, in the case of a plant, these traits would be its leaf shape or persistence, type of pollination or dispersal means (Knapp et al., 2010). As such, the air purification/regulation as an ecosystem service is linked to the ecological function of particle trapping, which in turn depends on the functional trait of the leaf surface [larger leaf area gives a greater particle capture potential] (Commissariat Général au Développement Durable, 2010; Chen et al., 2015). Furthermore, the pollination service depends on the insect attraction ecological function, which is related to the entomophilous trait.

Here are the main functional traits that are usually considered: root system, type of dispersion, type of pollination, phenology (e.g. time of reproduction), leaf anatomy, leaf persistence, leaf area, etc… Databases summarizing known traits for certain species exist. Here are the main ones:

- The LEDA Traitbase (https://uol.de/en/landeco/research/leda): The LEDA Traitbase provides information on plant traits that describe three key features of plant dynamics: persistence, regeneration and dispersal. It is focussed on the Northwest European flora.

- BiolFlor (https://www.ufz.de/index.php?en=38567): The database BiolFlor on biological and ecological traits of the flora of Germany covers almost 3660 species of vascular species including established and frequent casual alien plant species.

- Baseco (https://baseco.imbe.fr/): BASECO is a floristic and ecological database focused on the Mediterranean French flora.

- TRY (https://www.try-db.org/TryWeb/Home.php): TRY represents the largest database of plant traits that exists (11 850 781 trait records, 279 875 plant taxa, and 214 publications).

In this study, the TRY database has been mainly used to make a link between the functional traits and the ecosystem services on which the EVNATURB project is focused on (stormwater management, urban heat island mitigation and biodiversity preservation essentially).

3. Overview of current practices, disturbances and possible consequences

3.1 Analysis of existing species

A text-mining analysis was conducted to study the current NBS implemented in urban environments. Carried out using the SCOPUS database for peer-reviewed literature, the occurrence of some keywords used in publications on urban NBS from the appearance of the concept in 2016 until December 13, 2021 was studied. The keywords used for this search were: *nature-based* AND *solution* AND *city*. The analysis was then carried out for the titles, abstracts and keywords of the studied corpus (453 documents). The most publishing journals on this topic were found to be: Sustainability (MDPI), Urban Forestry and Urban Greening (Elsevier), Environmental Research (Elsevier), Science of The Total Environment (Elsevier) and Water (MDPI). Only the keywords appearing at least 8 times were conserved. Accordingly, the main types of NBS described in literature were found to be: green spaces

(82), urban forests (81), trees (25), green roofs (22), urban agriculture (19), recreational parks (18) and wetlands (8).

In addition, an individual analysis of some papers dedicated to green roofs was carried out. These documents were retained because they provided an exhaustive list of used/studied species with their relative quantities (e.g. the three species most present on the roofs were kept, or, the three species present on the greatest number of roofs). As a result, a list of 27 dominant (planted and spontaneous) plant species on green roofs used in temperate environments (Germany, Belgium, Canada and Switzerland) was obtained. Some plant functional traits which seem essential for ecological functions (water retention, evapotranspiration, gas exchange, particle trapping, pollen transfer) and ecosystem services (regulation of hydrological cycles, flood risks and climate regulation, air and water purification, pollination and support of biodiversity) were particularly studied. With the help of the TRY plant traits database (https://www.try-db.org; Kattge et al., 2020), a composite portrait of a typical plant has been created based on the 27 inventoried species (by averaging the numerical variables, and retaining the most common value for the qualitative variables; Table 1). As this analysis was carried out on a relatively limited sample, it would be interesting to do further research on a larger sample of rooftops or even with other types of NBS present in the city.

Table 1: Characteristics of the typical dominant plant on green roof in cities of temperate climate using data from the TRY database and a sample of roofs.

Characteristics (27)	**Lifespan (27)**	**Pollination (27)**	**Root system (27)**	**Persistence of leaves (24)**	**Leaf surface per plant (15)**	**Stomatal conductance per leaf area* (26)**
Typical plant	Perennial (14)	By insects (20), mainly bees (19)	Non-pivoting (14)	11 months	878 cm²	0.24 mol/m².s

** Transfer of water vapor or CO_2 through stomata. The number in parenthesis corresponds to the number of plants concerned (total number for the first line, number of the dominant trait for the second).*

Although this is an important result, it is not a panacea. The plant species are rather small and lack heterogeneity. Pollination of this typical plant is dependent on insects, especially bees, which makes it more vulnerable to disturbance. The modelled plant has a rather long leaf persistence time and average leaf surface and stomatal conductance. These trait values allow an important performance of water retention, evapotranspiration, gas exchange and particle trapping (among other ecosystem services). However, these functions and services can be influenced by the many disturbances that characterize the urban environment.

3-2 Disturbances due to global change

Often, ecosystem hyper-disruption is overlooked, especially in cities. Even when ecosystems are left to self-organize, there are always drivers of change such as climate change, land-use change, pollution, overexploitation and invasive alien species (Pereira et al., 2012). In the urban environment, disturbances are even more numerous, given the strong anthropogenic influence. Indeed, the world's urban population is steadily increasing; 34% of humans lived in cities in 1960 and have increased to 56% in 2020 (World Bank, 2020). Horticultural plants, which are very present in cities, are often the source of invasive plant spreading (Reichard & White, 2001). Human-induced drivers of change can then affect evolutionary trajectories (Palumbi, 2001). For example, heavy metal exposures have caused changes in the evolutionary properties of (resistance) plants living in contaminated sites (Wu & Kruckeberg, 1985). Another example is that in habitats disturbed by humans, plants interbreed more than in an undisturbed environment (Eckert et al., 2010). This is mainly due to the lack of pollinators. Indeed, even if humans do not directly act on an ecosystem, they still have an indirect impact via climate change or various pollution sources.

However, disruptions are not always sudden. Some of them can occur continuously like climate change. As already mentioned, the IPCC reports that *"Cities intensify human-induced warming locally, and further urbanization together with more frequent hot extremes will increase the severity of heatwaves"* and *"Urbanization also increases mean and heavy precipitation over and/or downwind of cities"* (IPCC, 2021). The increase of extreme events (drought, rainfall) in terms of intensity and frequency can clearly have consequences on vegetation (Zhang et al., 2021). Therefore, the selection of plants species that can survive water-deficits, especially on dry soil as green roof substrates is crucial (see Du et al., 2019). The consequences of climate change can also be temporary positive as global warming can advance the phenological phases of leaf development and delay the phenological phases of leaf senescence (Wohlfahrt et al, 2019).

3-3 Possible consequences of these disturbances on NBS

The multitude of disturbances present in the city can have multiple consequences on urban NBS, ranging from simple modifications of functional traits and/or populations of living beings to their destruction. Indeed, disturbances also called drivers of change can modify the functional traits of plants, create new ones or eliminate them. Some of these traits named "keystones" are very important for humans, as they interfere with many ecosystem services (Hevia et al., 2017). The modification or disappearance of such traits can therefore mean the decrease or the disappearance of many of their related services. The leaf surface of a plant is one of these "keystones" traits, as it is linked to many services such as the regulation of hydrological cycles, flood risk, micro-climate and the purification and maintenance of air quality. This trait appears to be most affected by land use change (Hevia et al., 2017).

The above-mentioned drivers of change can lead to the selection of plants that have certain functional traits. For example, urbanization can lead to the selection plants that are more tolerant to nitrogen and heat (Knapp et al., 2010). Human disturbances can also destroy parts of plant population or even the whole, even the specimen present on a site, thus reducing site-biodiversity. Indeed, a study on a Chinese island showed that the direct factors making small plant populations susceptible to extinction were human disturbances (Chen et al., 2014). According to Köhler (2006), floristic diversity of green roofs is mainly influenced by weather conditions (temperature and rainfall), so climate change can have a serious impact on this diversity in the future. The change of land use in the environment of a given NBS can alter the necessary conditions necessary for solutions' life cycle or for the delivery of its purposes, according to the complementary land use concept of Colding (2007). This concept is built *"on the idea that land uses in urban green areas could synergistically interact to support biodiversity when clustered together in different combinations"* (Colding, 2007). For example, private gardens adjacent to urban public parks would enhance bird diversity through the landscape complementation functions provided by native tree cover, berry bushes, ponds, or freshwater springs, which increase the likelihood of attracting species (Blair, 1996; Melles et al., 2003).

Destruction of populations and/or changes in environmental conditions can lead to the creation of new ecological niches, and thus the colonization of a NBS by new species. It can also change the dominant species that are most likely to provide ecosystem services. Indeed, according to Xie et al. (2018), the functional characteristics of dominant plant species on green roofs are important to provide several services. Drivers of change can therefore destroy natural equilibrium and can also change evolutionary trajectories through adaptation. Accordingly, the question of impoverishing the evolutionary trajectories of the species present can be raised. It would also be important to refocus human/non-human relationships on maintaining evolutionary potential (Lecomte and Sarrazin, 2016). Therefore, the risk of reducing or losing ecological functions and ecosystem services of urban NBS through human disturbances exists. For example, in non-urban environments, land use intensification is linked to the loss of functional traits (such as thin bark and large size for trees in Brown et al., 2013) and the erosion of several ecosystem services (such as the supply of firewood and construction wood in Brown et al., 2013; García- Llorente et al., 2015; Laliberté et al., 2010). This raises the question of whether the targeted ecosystem services are still being provided, and whether the original problems are still being solved despite the anthropogenic disturbances present in the city and their consequences. Accordingly, one can also question if we are still dealing with nature-based solutions at this level.

4. Recommandations

4-1 Species and soil/vegetation complex to optimize ecosystem services

Based on the analysis of some papers dedicated to green roofs (Catalano et al., 2016 ; Rivière, 2019 ; Lundholm et al., 2010 ; Köhler, 2006 ; Rochefort et al., 2016. Among others) presented in Section III-1 and the list of 27 identified species, traits have been related to some particularly ecological functions (and ecosystem service) for which we are interested in. Traits values were extracted from the TRY database.

Water retention:
Water retention allows the regulation of hydrological cycles and the risk of flooding.

It seems that taproots tend to favor the development of preferential water flows due to the formation of macropores. These macropores, potentially associated with preferential flows, would therefore promote an increase in hydraulic conductivity. Large and flat (non-curved) leaf, characterized by a hydrophilic tendency (contact angle less than 110°), as opposed to long and oval leaf would improve water retention.

Considering the other variables, the most interesting species in the list from a water retention point of view are *Festuca ovina* and *Poa compressa*, which have a large leaf area per plant (respectively 864 and 704 cm^2), a high stomatal conductance per leaf area (0.68 and 0.57 $mol/m^2/s$) and long leaf persistence (6 and 18 months).

Evapotranspiration:
Evapotranspiration allows the regulation of hydrological cycles, flood risks and the local climate (especially temperature).

Canopies with large leaves have a higher surface temperature compared to smaller ones. It is due to the higher thickness of the boundary layer (which would therefore limit the effects of surface cooling by convection). Physiologically, this reflects a higher transpiration (and therefore a loss of water) for the plant with large leave surfaces. Small leaf, especially those characterized by low width, seem suitable for hot environments.

The most significant traits favoring evapotranspiration are then: LAI (Leaf Area Index, characterizing the size of assimilatory surface of a crop), leaf persistence and stomatal density (characterizing the interaction between the plant and the atmosphere).

The most interesting species inventoried into the list from evapotranspiration point of view are *Festuca ovina* and *Poa compressa*, which have a large surface area of leaves per plant (respectively 864 and 704 cm²), a large conductance of stomata per leaf area (0.68 and 0.57 mol/m²/s) and long leaf persistence (6 and 18 months).

Particle trapping:
The trapping of particles allows the purification and maintenance of air and water quality. This function is mainly conditioned by the leaf surface.

The species that have the largest leaf areas per plant are in descending order: *Trifolium repens*, *Trifolium arvense*, *Vicia sativa*, *Plantago lanceolata*, *Festuca ovina*, *Taraxacum campylodes (officinale)*, *Poa pratensis*, *Trifolium campestre*, *Poa annua*, *Poa compressa*, *Bromus tectorum*.

N.B.: There are lot of missing data in the TRY database for the leaf area per plant variable, and many species have not been taken into consideration.

Pollen and seeds transfer:
The transfer of pollen represents a vector of biodiversity through the dissemination it generates, but also through its contribution to insect populations.

The traits identified in relation to pollen transfer are: the means of pollen transfer (by wind, insects, etc.), the lifespan of the plant (an annual plant will produce pollen every year, a biennial every 2 years, a perennial it depends), and the flowering period. Note that there no information about the flowering period in the TRY database.

The most interesting species for pollination and support for biodiversity via pollen are (in alphabetical order, in bold the annual species which therefore necessarily flower every year):
Allium schoenoprasum, *Erigeron annuus*, *Geranium pusillum*, ***Lactuca serriola***, ***Medicago lupulina***, *Petrorhagia saxifraga*, ***Polygonum aviculare***, *Taraxacum campylodes (officinale)*, ***Trifolium campestre***. Indeed, these species can be pollinated by many species of insects.

To a lesser extent, the following plant species can also support pollination via insects (in alphabetical order, annual species in bold): ***Arabidopsis thaliana***, ***Cerastium semidecandrum***, *Plantago lanceolata*, *Sedum acre, Sedum album*, *Sedum sexangulare*, *Sedum spurium (hybridum)*, ***Trifolium arvense***, ***Vicia sativa***, ***Viola arvensis***. Indeed, these species are pollinated by fewer kinds of insects than the previous ones or may have other means of pollination (autogamous or by the wind).

Table 2: Relationship between traits, ecological functions and ecosystem services

TRAITS	FUNCTIONS	SERVICES
Leaf Area Index (LAI) Leaf persisitence Leaf shape Root system	Water retention	Regulation of hydrological cycles Regulation of the risk of flooding
LAI Leaf persisitence Stomatal density	Evapotranspiration	Regulation of hydrological cycles Regulation of the risk of flooding Regulation of micro-climate (temperature)
LAI	Particles trapping	Purification and maintenance of air quality Purification and maintenance of water quality
Pollen transfer medium Life time Flowering period	Pollen and seed transfer	Pollination Support for biodiversity (insects, etc.)

4-2 How to choose the species regarding the disturbances?

One of the objectives of NBS is to provide environmental benefits (see IUCN and European Commission definitions). Nonetheless, the main goal is to the conservation of biodiversity. For this purpose, it may be a good idea to use local plant species, with species already present in the city where the NBS is implemented. As a result, vegetation populations will be larger and therefore more viable. This is important as small and range-restricted populations are highly vulnerable to extinction (Terborgh & Winter, 1980; Gilpin, 1986). The establishment of NBS in the city can also be an opportunity to introduce species that were not initially present in the urban environment, but in its surroundings, hence increasing biodiversity in the city. There are already initiatives that promote and facilitate the use of local wild species such as the French label "Végétal local" (Végétal local; https://www.vegetal-local.fr/). However, will these local species be able to cope with disturbances like global warming? Perhaps it would be better to plant exotic (non-invasive) species that can withstand droughts for example or rising temperatures? In support of this argument, one study showed that in North America, the phenology of exotic species adapted better to climate change than native species (Wolkovich et al., 2013).

Another solution is to find and install plant species that can cope with the disturbances present in the city, such as "resistant" or ruderal species, or species that have been proven to work in a given context in the face of a given disturbance. The rationale behind this approach is the concepts of ecological resilience, which is the ability of a living system to recover the structures and functions of its baseline state after a disturbance (Holling, 1973), and resistance, which is the ability of a system to remain fundamentally unchanged when subjected to a disturbance (Grimm & Wissel, 1997). The idea is to return to the initial trajectories, before disturbances (or new favourable ones). However, this aspirational target is not always guaranteed. In the case of new evolutionary trajectories, one can speak about transformability, which is the ability to create a fundamentally new system when ecological, economic, or social structures make the existing system unsustainable (Walker et al., 2004).

In this sense, anticipating changes in eco-evolutionary trajectories by experimenting or studying correlations in urban environments could be an interesting platform to explore.

4-3 What about future practices and maintenance?

The previous section raised the question of how to deal with these disruptions and their consequences for NBS in the city. It can also relate to the question of ensuring the sustainability of the sought solutions. Therefore, it could be interesting to have ecosystems that are well-maintained over time and which are autonomous with planted and spontaneous species that reappear from one year to another or reproduce on site. Eventually, new colonisations that replace plants that have disappeared from the ecosystem can appear. However, the question of how to achieve this sustainability is raised. The idea is to work on the long term, to tap the full potential of the species' life cycles, and to anticipate the drivers of change and their consequences. For this purpose, urban NBS could be eco-designed, hence accommodating for life cycles and natural adaptation. Eco-design is based on the fact that: *"the environment helps to define the direction of design decisions and the environment becomes a co-pilot in product [here the NBS] development"* (Brezet, 1997). There is also the question of NBS-derived ecosystem service sustainability. But, is there a will to maintain all of these services as much as possible on the long term? Or target one or more in particular? The purpose is to move towards a dynamic ecological balance that provides ecosystem services, hence maintaining the durability of the designed/implemented NBS.

Regarding the management of NBS in cities for coping with disruptions, a legitimate question arises: do we let "nature" take over or do we accompany it? It would be probably a good idea to let nature take over more often in urban NBS, without direct human intervention or just the bare minimum, such as an annual maintenance of green roofs, the removal of invasive plants, etc. This type of *laissez-faire* management encourages the development of spontaneous species that are important for the functioning of ecosystems (Couvet & Ducarme, 2018) and allows ecosystems to become somewhat self-organized. Ecosystems are thus closer to a functional natural state It also reduces the financial, labour and time costs associated with NBS maintenance. Nesshöver et al (2017) stress the fact that NBS governance must be adaptive. Indeed, management must respond to the "reality of the field" and react to unexpected events. Lambert and Donihue (2020) go further to stress that evolving urban biodiversity requires incorporating evolutionary perspectives into management for these efforts to succeed given the dynamic nature of the urban environment. It is also important to take into consideration the landscape's heterogeneity, the ecological dynamics and the evolutionary consequences on biodiversity, i.e. to have an evo-centric approach (Lecomte and Sarrazin, 2016). Thus, solid progress towards socio-eco-evolution in the city is needed (Des Roches et al., 2021). Accordingly, human societies, non-human living beings and their ecology and evolution, as well as their interactions should be better accounted for. Whether in eco-design or management, it could be interesting to mimic nature and its ecosystems in an effort to understand their behaviour in the face of various disturbances.

Conclusions

Urban environments are very complex and challenging ecosystems. Drivers of change influencing this particular context are numerous. On one hand, the increase of urban populations and the resulting intensifications of urban cover can modify the water cycle (by inducing imperviousness and heat storage), facilitate invasive species spreads and create various types of pollution. On the other, climate change can intensify the occurrence of extreme events like flooding or heat waves.

The use of NBS is therefore one of the main means to help cities adapt to these constraints and to make them more resilient. For this reason, NBS for climate change adaptation (called Nature-Based adaptation Solutions, NBaS) are starting to gain prominence in scientific discourses (IUCN French Committee, 2019). The increase in related scientific literature supports this statement.

Through the (re)introduction of nature, NBS also represent a good solution for biodiversity and for its effective return to the city. However, if the constraints of global changes on societies are now obvious and well documented, the same is probably also true for the non-human living world. Nevertheless, the latter's response to these constraints remains uncertain. To our knowledge, scientific literature has rarely addressed this question. Thus, the use of NBS for mitigation or adaptation purposes in cities has to be examined with great caution. NBS are usually implemented to mitigate or to adapt the environment to the current situation, often leaving aside the need to forecast the evolution of future constraints and how NBS will respond to them. This stationary point of view has obviously some limitations.

Indeed, resistance to strong constraints also has its limits for city biodiversity. Accordingly, it is difficult to predict whether introduced or local species will survive extreme conditions which they may face. It is also unclear whether this newly introduced nature will be able to provide the ecosystem services for which it was initially planned for. Climatic hazards, such as various types of pollution, can indeed alter some of these "keystones" traits.

This clearly questions the way of approaching the introduction of biodiversity in cities. The time has come to question whether Nature-Based Solutions should be considered as a way to rethink our cities in their entirety. A paradigm shift is surely necessary to move from business-as-usual approach “adapting to what?” all the time, to rather “adapting what to what?”, taking into account the possibilities of the territory and its limits.

This approach requires the adoption of a systemic and dynamic approach that gives the diversity, complementarity and renewal of species an important role to ensure services, their sustainability and their adaptability. A stronger involvement of ecologists is required to question these points at scales that go beyond that of the infrastructure on which NBS are often installed. It is about understanding better understanding how a particular NBS fits its surrounding environment, and how its complementarity with the whole system can benefit everyone.

The acquisition of knowledge in these fields should be fed by past and current experiences. This requires experiments and capitalizing on feedbacks from existing NBS. A recent initiative, the Life ARTISAN project (Increasing the Resilience of Territories to Climate Change by Encouraging Nature-Based Adaptation Solutions, www.life-artisan.fr), can contribute to this task. ARTISAN aims to identify the obstacles and levers related to the implementation of NBS. By following several demonstrator NBS sites, it will provide information on the sustainability of the expected benefits.

In addition, a more global reflection integrating local authorities, engineering design offices and urban planners could be beneficial. The objective is to link aspects of biodiversity with planning, public policies, and climate, in order to share the knowledge with more technical and decision-making organizations. This framework should allow a more successful and cautious reintroduction of nature into cities hence avoiding “greenwashing”

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