Projet ANR 17-CE22-0002-01
EVNATURB
Programme JCJC 2017

Deliverable 3.1: Report on local environmental constraints and objectives related to NBS implementation & Definition of quantitative indicators

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Aout 2021

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ABSTRACT

The objectives of this deliverable is to understand what hinders the development and sustainability of Nature-based (Blue-Green) Solutions in the city and what could help to deploy them on a large scale. For this purpose, various professionals working on Nature-Based Solutions in the city in France were interviewed between 2020 and 2021, in the academic, institutional and operational sectors (or even at the interface between them): researchers in ecology or hydrology, IUCN (International Union for Conservation of Nature) project manager, project managers at the Regional Biodiversity Agency, director and natural environment manager of a watershed union, agro-economists engineer among others. They were asked what are the barriers and potential opportunities for Nature-Based Solutions implementation and sustainability in city.

By analyzing their answers, it emerges that the obstacles are more often cultural, political or financial than technical. The potential levers often mentioned are education and awareness-raising at all levels, especially for elected officials and the general public. Regulations such as the PLU (Local Urban Plan) and new funding for more natural spaces in the city also seem to be means of promoting Nature-based Solutions in urban areas. These interviews with diverse professionals directly involved in Nature-Based Solutions in cities allow to give real courses of action to be taken to democratize these solutions throughout the French territory, or even internationally.

In addition, a list of quantitative indicators is proposed to assess NBS performances and promote their implementation.

1. INTRODUCTION

1.1. The ANR EVNATURB project

The ANR EVNATURB project (2018-2022) "*Evaluation des performances écosystémiques d'une renaturation du milieu urbain"* aims to develop an operational platform to assess some of the eco-system services (i.e. storm water management, cooling effect, or biodiversity conservation) provided by Blue-Green Solutions (BGS) at the district scale, and to promote the re-naturation of cities (HM&Co, 2017). This project has several objectives:

I. Coupling hydrology, thermic, urbanism, biodiversity and the corresponding ecosystemic services;
II. Characterizing the spatio-temporal variability of the related processes over a wide range of scales by (i) the implementation of a complex, portable and high resolution monitoring, and (ii) the use of adapted analysis and modelling tools;
III. Developing a scientific network devoted to BGS monitoring and contribute to expand knowledge and fulfill the lack of feedback concerning the functioning of existing BGS;
IV. Characterizing the implementation of BGS infrastructures by taking into account local socio-environmental stakes and constraints, and define some quantitative indicators relevant for the development project (certification, labeling, compliance with local regulations, continuity with surrounding biodiversity, etc.).

This deliverable (3.1) is part of Objective IV and concerns the local socio-environmental stakes and constraints in relation with BGS/NBS implementation.

1.2. The concept of Nature-Based Solutions

In order to adapt to current trends and dynamics, the term Blue-Green Solutions (BGS) has been replaced by that of Nature-Based Solutions (NBS). The International Union for Conservation of Nature (IUCN) defines NBS as: "actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (IUCN, 2020). The European Commission defines NBS as: "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such 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, 2020). These two definitions are often used as references, but others also exist. Indeed, there are many definitions of NBS, but most agree that these solutions are beneficial to the environment and humans, rather than being just focused on nature's restoration and conservation (Sarabi et al., 2019).

The NBS concept is mainly European, and is often associated with climate change, urbanization, water management, urban heat island, air pollution, well-being, human-health and sustainability (Templier, 2020). The concept is recent and is still emerging (Pauleit et al., 2017; Dorst et al., 2019) with many related scientific publications (975 documents found with Scopus with the term "nature-based solutions" in titles, abstracts and keywords on June 10, 2021 in a search performed by the Authors). On the other hand, it is even considered by some

scientists especially in the field of nature conservation, as “yet another buzzword” (Eggermont et al., 2015).

2. OBJECTIVE

Even if the concept of NBS is currently a hot topic, it is challenged by its physical implementation which is often complicated by many factors (Kumar et al., 2020). These difficulties are particularly pronounced in the urban environment due to its dense nature. Indeed, the implementation of NBS in urban settings raises a number of operational questions: How to adequately integrate them into the concerned context? How to evaluate their costs and benefits? How to design these solutions for meeting the different challenges? Etc. (Raymond et al., 2017a). In addition to these issues, there are many other barriers facing the implementation of sustainable NBS in cities. With the help of a dozen people working on NBS in France, this study aims to identify these barriers are and to highlight the levers that can be used to overcome them. By responding to this problem, answers for subsequently upscaling NBS in cities can be obtained.

3. METHODOLOGY

For this study, several actors working on NBS in France were interviewed. In order to cover the whole spectrum of specialities, interviewees from the academic, institutional and operational circles were chosen. Accordingly, the interviewees' profiles are: Ecologist and project leader at the Regional Biodiversity Agency, researchers in Hydrology or Ecology at the Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning (CEREMA), the French Research Institute for Development (IRD) and the Museum of Natural History, general manager and head of the planning and natural environment department of the Intercommunal Syndicate for Hydraulic Development of the Croult and Petit Rosne Valleys, project manager at the IUCN, independent agro-economist and project manager at the Gally design office, project manager in a design study at Topager, technical manager at SOPRANATURE (green roofs and facades of SOPREMA, building, waterproofing and insulation company), and a responsible of the EcoQuartier mission at the French Ministry of Ecological Transition. More details are provided in Table 1.

A questionnaire was especially constructed for this purpose. Most of the questions, were developed by the Authors, while another part was adapted by the first Author according to each interviewee's profile. The questionnaire was divided into six parts: (i) context of the interview, (ii) personal information, (iii) NBS in the urban environment, (iv) biodiversity and the ecosystem functions of these solutions, (v) constraints, barriers and levers for the implementation and the sustainability of these solutions, and (vi) perspectives. The questions on constraints, barriers and levers were as follows: "What are the external constraints that can influence the selection and implementation of NBS?", "What are the climatic, technical, Local Urban Plan, land use or characteristics, building rules, certifications or labels constraints, etc.?", "In your opinion, what could be the obstacles to the establishment of sustainable of NBS in cities?" and "What are the levers that could help promote the establishment and durability of NBS in cities?".

The interviews were conducted in French by the first Authors via videoconference techniques using the Meet Jitsi website (https://meet.jit.si/) at the following address: https://meet.jit.si/EntretiensSolutionsFondeesNature. Each interview lasted between 45 minutes and an hour and a half. They were carried out between November 17th, 2020 and March 4th, 2021. The first hour of the interviews was recorded (image and sound) directly via the Meet Jitsi site and saved on the Dropbox cloud. The complete interviews were recorded (sound only) via a voice recorder on a digital tablet. In addition to handwritten notes taken during the interviews, full transcripts were made from the video and audio recordings.

Word clouds were created with the answers to the questions on constraints and barriers on the one hand and on levers on the other hand, in order to highlight the words most used by the interviewees for these answers (the more often a word is quoted the bigger it appears in the cloud). The word clouds were made with R and Iramuteq software using the active forms of the words (verbs, nouns, adjectives) cited at least 5 times for barriers and 3 times for levers. Words that did not provide information were removed (put, lot, thing, good, case, addition, false, feel, today, small, real, relate, back, subject, start, true, set, show, fact, begin, end, sense, remain, bite, area, bring, percentage, type, part, talk, necessarily). Words of the same family have been merged.

Nb	Function	Organization	Acronym	Website	Sector	Date
1	Head of studies	Regional Biodiversity Agency	ARB	https://www.arb-idf.fr/	Interface	17/11/20
2	Regional animator	Regional Biodiversity Agency	ARB	https://www.arb-idf.fr/	Interface	27/11/20
3	Researcher in hydrology	Center for studies and expertise on risks, environment, mobility and development	CEREMA	https://www.cerema.fr/fr	Academic	04/12/20
4	Head of the urban planning & natural environment department	Mixed syndicate for the hydraulic development of valleys	SIAH	https://www.siah-croult.org/	Operational	08/12/20
5	NBS Project manager	International Union for Conservation of Nature	UICN	https://uicn.fr/	Interface	14/12/20
6	General manager	Mixed syndicate for the hydraulic development of valleys	SIAH	https://www.siah-croult.org/	Operational	16/12/20
7	Research director in ecology	Institute of Research for Development	IRD	https://www.ird.fr/node/8	Academic	07/01/21
8	Project manager	Gally's design office (design, plants, urban biodiversity and agriculture)	GALLY	https://www.lesjardinsdegally.com/agence/le-bureau-detudes-de-gally	Operational	20/01/21

9	Project manager / Head of mission	Topager (Edible and wild urban landscape) / Museum of Natural History	TOPAGER MNHN	http://topager.com/ https://www.mnhn.fr/fr	Operational & academic	03/02/21
10	Researcher in ecology	Center for studies and expertise on risks, environment, mobility and development	CEREMA	https://www.cerema.fr/fr	Academic	04/02/21
11	Technical manager	SOPRANATURE (Vegetation systems)	SOPRA	https://www.soprema.fr/fr/nos-produits/vegetalisation/sopranature	Operational	19/02/21
12	Responsible of the EcoQuartier	Ministry of Ecological Transition	MTE	http://www.ecoquartiers.logement.gouv.fr/	Interface	04/03/21

Table 1. List of interviewees with their reference number, function, organization, French acronym and website of their organization, sector of activity and the date they were interviewed. In the rest of the deliverable, the numbers in brackets correspond to the reference numbers in this table to indicate which interviewee is cited.

4. PRESENTATION OF THE RESULTS

The results of the interviews are divided into two parts. The first part lists the constraints and difficulties encountered by the actors in implementing NBS. The second part gives the levers for an effective implementation under a framework of sustainability. The word clouds show the most used words in the answers to the questions on the constraints and barriers to the implementation of NBS in the city on the one hand and on the levers on the other hand (Figure 1).

A. B.

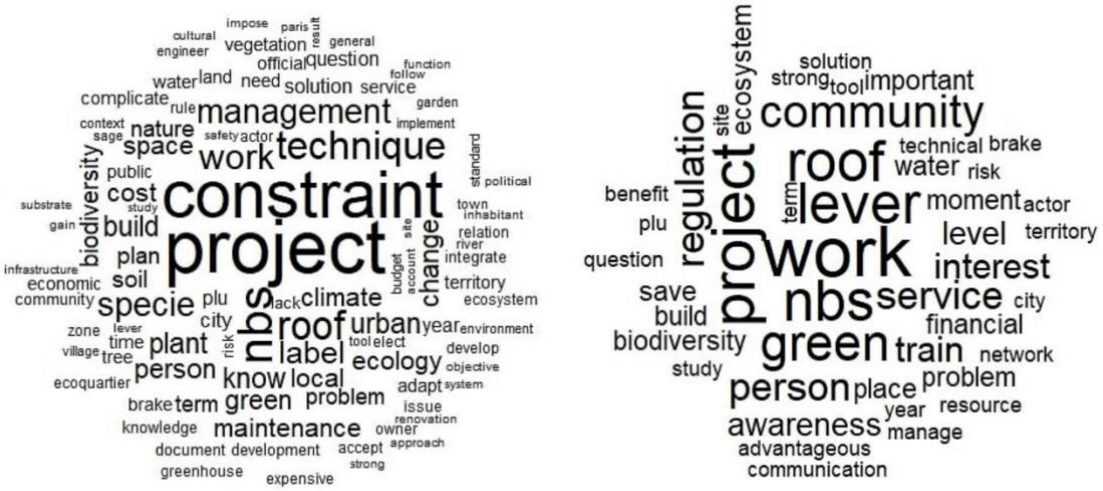

Figure 1. Word clouds with answers to the questions on constraints and barriers (A.) and levers (B.) to the implementation and sustainability of NBS in cities

4.1. Constraints and barriers to the implementation of sustainable NBS

According to the word cloud (Figure 1. A.), the constraints to urban NBS are related to projects, technique, management, biodiversity, people, roofs, labels, etc.

4.1.1. Confusion due of multiplicity of terms and lack of knowledge

The interviewed ecologist points out a problem which is the *"multitude of concepts that designate more or less the same thing, that come together to designate nature-related elements: nature-based solutions, green and blue solutions, green and blue webs, nature in the city, ecological engineering, urban restoration, green infrastructure, etc."* (1) The same person adds: *"I think what you call NBS, is not called so by the people that implement them, especially in urban areas. NBS is a new concept, not very common in communities, they'll talk more about a landscape project, a wetland or a retention pond, a park or a garden, etc."* (1) For him, this term is mainly used by scientists. The problem of connected or even synonymous terms of NBS has already been raised in scientific literature (e.g. Nesshöver et al., 2017). The multiplicity of terms can be counterproductive, as it makes research more difficult to conduct. Accordingly, there is a risk of misunderstanding due to contested nomenclature that might lead to a replication of efforts. Moreover, the IUCN project manager said that the term NBS *"[is] not always well-used (one of my roles is to re-define it to ensure*

that it is used well)" (5). It is therefore necessary to recall the adopted definition to homogenise the discourse among different stakeholders.

Several interviewees pointed out that there is still a lack of data and knowledge on NBS in urban settings. Even if studies on the subject have multiplied in recent years, there are still grey zones that need to be filled (Fernandes et al., 2018; Kabisch et al., 2016). Indeed, ecosystems and the urban environment are complex and their interrelationship is difficult to analyse. Thus, soils are often underrepresented and tools enhancing soil quality are needed according to one interviewee. An interviewed researcher in Ecology said that it was necessary to *"increase scientific knowledge on the components of biodiversity that allow to maximize ecosystem functions and services"* (10). Indeed, according to literature, there is little evidence on the multiple benefits of NBS (Sarabi et al., 2019; Short et al., 2019).

A project leader on NBS said: *"There is a lack of indicators that reveal the efficiency of NBS. [...] It is difficult to evaluate the gains resulting from NBS, especially when taking into account all the costs and benefits, and not just the targeted problem. It is accordingly hard to mobilize stakeholders, due to the lack of concrete proof on returns."* (2) According to Kabisch et al. (2016), there is a need to develop indicators that incorporate environmental performance, health and well-being, citizen engagement, and maintenance/transferability. People who implement NBS need to be reassured that these solutions will deliver the expected benefits, otherwise investing in them might be useless. It is also important to mention that long-term studies (i.e. over large time spans) on NBS in cities are still too few, especially those dealing with the longevity of these solutions' advantages.

4.1.2. Greenwashing: NBS are not as eco-friendly as portrayed and failed cases of NBS give the impression that NBS are not efficient solutions

One of the risks of environmental projects is greenwashing. Indeed, sometimes the ecological aspect of certain projects can be oversold, and thus the concept of NBS can be used as a means for greenwashing (Moosavi et al., 2021). The project leader at the regional biodiversity agency thus refers to *"NBS can be used indiscriminately, for example referring to false ecological engineering"* (2). One researcher explains it this way: *"The risk with green roofs is that they oversell ecological interests […] services and benefits that might never be provided at the end."* (7) Under this context, green roofs can be considered as a mono-specific lawn that represents little interest for biodiversity. Thus, many private NBS commitments are presented as offsets, which often imply greenwashing (Seddon et al., 2021).

Failed examples are also a major issue. The general manager of the water management union said that there were bad examples in which NBS *"brought disadvantages and increased risks"* (6). He made particular reference to bad practices in a reopened river zone such as *"uncontrolled picnics, quads, and motocross activities"* (6) even the accumulation of waste, and the excessive consumption of alcohol. Accordingly, when NBS planners observe such effects, they might re-consider the implementation of their projects.

4.1.3. Biodiversity is not in the foreground of our societies

Generally, biodiversity and its erosion are not in the foreground of our societies. For example, in the United States, most people prioritize other issues such as terrorism, health or the economy (Novacek, 2008). Presumably, these concerns are the same in Western societies such as France. The recent health crisis due to covid-19 has undoubtedly increased health

concerns and consequently pushed the biodiversity crisis into the background (Goymann, 2020). The economy is also often at the center of concerns, leaving little space for environmental issues (Giddings et al., 2002). The person responsible for urban planning and the natural environment of the hydraulic union confirms that in urban development, biodiversity is not the priority: *"Designing a housing project with a focus on biodiversity as a priority can be complicated, since it comes second."* (4) Even within environmental issues, the project manager of the Regional Biodiversity Agency told the Authors that protecting biodiversity is not a priority: *"[the Ministry is really focused] on adapting to climate change, climate change in general and renewable energies."* (2) Biodiversity often takes a back seat behind aesthetics (or agronomy), as one ecologist noted regarding NBS substrates: *"Today, substrates are made rather by landscapers, to have an agronomic or ornamental aspect. In any case, it does not consider the type of plants i.e. wild plants, or local plants, etc. […] And that's an issue in NBS: to move towards more local plants."* (1) Another ecologist noted, *"The fact that there are no landscapers, and therefore no ecologists on the project either, can raise the question of how someone (i.e. the architect) who does not necessarily have this eco-friendly culture is going to put in place everything."* (9). Indeed, the implementation of NBS in cities is often done through an opportunistic approach (1).

Despite of what was presented, biodiversity seems to be increasingly taken into consideration, particularly in the legislations of urban planning, according to a person from the hydraulic union. But as she explained, this approach is often more oriented towards humans: *"Concerns today about the impact of projects, the long-term vision of a site, the integration of nature, having green corridors, having less concrete, and more vegetation remains within the framework of a vision of an environment adapted to humans: "You are going to be in a neighbourhood with lots of trees"."* (4)

4.1.4. Technical problems that can often be overcome

Many interviewees reported that technical issues were not the most difficult elements to solve. In fact, most of the time, technicians know how to eliminate these types of constraint thanks to their knowledge and to their field experience. So an ecologist said, *"Yes, there are technical constraints, but they can be easily overcome, if you do things in order with specialists it can be done."* (1). There is even a technical handbook specific to NBS that can help people work on them (Eisenberg, 2019). However, not all technical constraints are easy to overcome. While this might be the case of technical constraints serrated to buildings, the technical constraints related more to ecology seem harder to overcome. Indeed, as observed, there is a lack of knowledge and skills in this field. A hydrologist told the Authors that we should strive for simplicity*: "Simple things should be done. NBS cover a lot of things: some very technical and some more elemental that according to me are closer to NBS and are better than the very technical aspects."* (3)

4.1.5. The challenge of adapting NBS to local climate and climate change

In our questionnaire, we considered the climatic factors as constraints, because they require a significant adaptation of NBS accordingly (e.g. choice of plant species). Such a task is not always easy and requires considerable knowledge. Ideally, it is better to use native plants adapted to the local climate and to adapt the plant range on a case by case basis. However, for practical reasons, this is not always possible.

In addition, climate change and its consequences are also very important to consider and species that can cope with it in the near-future must be found (Hobbie and Grimm, 2020; Nesshöver et al., 2017). But this is not obvious, as the project manager of Gally design office said: *"If I plant trees, must still be there in 20 or 30 years. How do I select them then?"* (8). A researcher asked the same type of question: *"In anticipation of climate change, shouldn't we start considering species that are not necessarily local, but more adapted to periods of drought (e.g. Mediterranean species)?"* (10). Even if some people try to find solutions to answer this problem, it is not yet the norm and much more efforts are still needed.

To limit greenhouse gases and therefore mitigate climate change, it might be interesting to consider short-term actions, for example trying to use local materials for the substrate of a green roof. In this regard, a seller of green roofs explained that this is something that can be very complicated to do in practice. Indeed, it is necessary to *"[extract] the soil at the right time during the construction phase, [characterize it] in the laboratory, [use it] partly on the roof [after having it mounted]."* (11) Mounting the soil is just as complicated: *"You have to put it in big bags, which are extremely expensive. This means that you have to set up a bagging workshop on site or you have to move the local material onto a platform with semi-trailer trucks to use this material, bag it as is or slightly rework it with lightening or structural elements, to bring it back to the site for use."* (11)

4.1.6. Too little funding for NBS

There are also economic constraints, including the uncertainty about the costs of NBS. For example, one hydrologist (3) said that NBS are perceived as more expensive than conventional solutions. Such observations are also found in literature on green infrastructures (Dhakal & Chevalier, 2017). The technical manager of SOPRANATURE tells us *"the economic constraints of the project mean that green spaces are the fifth wheel. When there are savings to be made, they are found in green spaces. The same applies for building, when savings are to be made, it is often vegetation roofing that will suffer."* (11) The ecologist from the Biodiversity Agency told us on this subject: *"We are afraid of having to manage ecosystems for too long. Whereas with good grey infrastructure, we're sure how much it's going to cost us, at least in the short term."* (1) His colleague added: *"Big problem of financing complicated the mobilization of these subjects, in particular because NBS are very broad, […]. Many terms already used before. So funders are wondering what NBS have to add."* (2) She also said it's hard to get a quick return on investment. According to the European Commission's 2015 report (Davies et al., 2015), the cities' budgets for green spaces are very small. Specifically, the lack of dedicated funding for NBS implementation in cities has already been highlighted (Droste et al., 2017) and financial incentives to use NBS are also missing (Li et al., 2019).

4.1.7. Too little space in the city and land prices are often high

Something that has not been mentioned much, but which is a characteristic reality of the urban environment, is the lack of space and the price of land which can be very expensive in some cities like Paris. Indeed, the average built density ((footprint x building height)/study area) in Paris is equal to 2; in comparison, the built density of an individual housing operation is about 0.3 (Intermezzo, 2011). In April 2021, the average price of a square meter in Paris was of €10,780 (EffiCity, 2021). This problem hardly concerns green roofs which are not in direct competition with other infrastructures, because they can be inserted on the top of buildings. However, land characteristic is a major problem for ground NBS. The city is a built

environment which can be very dense and NBS can require large spaces that are difficult to find in such an environment (O'Donnell et al., 2017). This lack of space can even lead to the redesign of an urban project (4). On this subject, an interviewee points out that NBS can take up a little more space than traditional solutions. He added: "Today, we are already struggling to get people to accept more open space in development projects, more green spaces or land. Projects are often far too dense. So there's an issue of creating space for these NBS." (1) The price of land can also be a disadvantage for the implementation of NBS and sometimes conventional infrastructures can be more profitable, especially on the short term. This competition for land use has already been discussed in the literature (Kabisch et al., 2016).

4.1.8. Too little space for NBS in the regulations

Regulations can be a constraint for the development of NBSs in the city, because as one interviewee points out *"planning documents today do have a space for these NBS."* (1) He cites the PLU (i.e. Local Urbanism Plan) and the SCoT (i.e. Territorial Coherence Scheme). An NBS officer (2) gave an example, that an NBS was to be implemented in a zone labelled as "to be urbanized" in the PLU, and that the project in which she was involved in could finance NBS only in zones classified as natural in this document. This example shows how regulations can be an obstacle to implementation of NBS in cities. At present, French regulations do not sufficiently encourage the implementation of NBS in cities. Kabisch et al. noted back in 2016 that urban administrations may lack the information on legal instruments and requirements for implementing NBS.

4.1.9. Social and cultural barriers are often predominant

An ecologist declared: *"I would say the first constraint to implementing NBS is cultural. It's the fear of using nature versus grey infrastructure. […] We're afraid of these solutions because we don't find them reliable."* (1) The hydrologist (3) also mentioned the fear that NBS will not work, that is also documented in literature with the fear of lower performance of green infrastructure versus grey infrastructure (Dhakal & Chevalier, 2017). This cultural barrier seems to be present at all levels, whether from the general public, communities, urban planners, etc. Thus, there is a lack of citizen awareness, support and interest in NBS (Sarabi et al., 2020; Wamsler et al., 2020).

Later, the ecologist adds: *"People are afraid of nature. […] People still have a rather negative relationship with nature, even if it is changing. We see it in the case of the wetland in Vignois, there are complaints from inhabitants about mosquitoes. It's a daily job to try and get people to accept it."* (1) This fear of nature may relate to the fear of the unknown discussed by Kabisch et al. (2016) in the face of uncertainties and risks of implementing NBS in cities, as well as the changes these may induce in urban planning. This fear of nature can also relate to real problems called ecosystem disservices such as the mosquito bites discussed here. Ecosystem disservices are inconveniences caused by nature can be diverse in cities (Lyytimäki et al., 2008).

The responsible of the urban planning and natural environment in the hydraulic union mentioned many human-related barriers: *"Often statements such as "Biodiversity is very good, but not in my place!" are common. From the moment when vegetation is allowed to grow, having a height of 50 cm of vegetation […] in an urban environment is not something acceptable, because it does not look clean. […] We try to make something beautiful so that*

that it becomes better accepted. […] We can also have complaints because of pollen and its associated allergies" (4)
Another aspect of social barriers is the cost of organizing services or changing roles within communities (3).

4.1.10. Lack of political will

Another important obstacle facing NBS in cities is the lack of political will. Indeed, the development of such solutions requires political will from elected officials, but that is not always the case. This lack of political will was also identified as a major constraint to the implementation of NBS in cities by Sarabi et al. (2020). Moreover, the representative of the Biodiversity Agency (2) told us that even if the political will was to be there, municipalities and elected officials can change quickly and give space to more people less concerned NBS. This can compromise projects undertaken during previous mandates. In France, municipal councils and mayors have a six-year mandate (Ministère de l'Intérieur, 2020). In comparison, the implementation of an urban project takes at least ten years, often much longer than a political mandate (Bourgade, 2000). The problem of changing administration was mentioned by Kabisch et al. (2016). Davies et al. (2015) also discussed the long-term vision for green spaces that must be modified due to policy changes. *"It would be necessary that the municipalities or agglomerations have a real desire, to be the driving force, in the PLU to reinforce the presence of biodiversity component on their territories"* (4), said a person from the hydraulic syndicate.

4.1.11. Lack of maintenance and durability

The ecologist of the Regional Biodiversity Agency said *"There is usually a lack of monitoring over time, that is to say a before/after assessment. Also, there is a lack of understanding if there has been a gain for biodiversity and if certain ecological functions were affected, […] to make an annual follow-up for example is difficult, […] And so is the fear of part of communities, in not knowing what will work over the long term."* (1) The responsible of the natural environment of the hydraulic union (4) gives an example of the watercourse that was reopened in 2014, where only one fauna and flora inventory had been carried out. According to the responsible, it would have been better to have at least one survey every two years. She also explained that long-term monitoring is important to know, for example, *"how the stream behaves after dry weather, or rainy weather, to see how the vegetation manages to recover."* (4) She added that it was tricky to find *"a good boundary between a stream that we want to be natural and the urban area."* (4) NBS are partly made up of living beings and are therefore in constant evolution thus requiring continuous maintenance. However, this maintenance is not always taken into consideration in NBS projects (Kabisch et al., 2016). The problem of lack of monitoring and/or maintenance may be related to the fact that administrations have a short-term view that should evolve into a long-term view to favour NBS (Burch, 2010; Sarabi et al., 2020). The problem of maintenance raises a number of questions: *"Who will do the maintenance? How do we make sure we have sustainable funding for this maintenance?"* (5).

Although maintenance can be seen as a barrier to NBS, it can also represent an opportunity, as one person from the water development union (4) explained. Indeed, the projects on which they work must manage rainwater at the plot level, and when the basin is buried, it is maintained only in the first years, and then no longer as it is not visible. So the syndicate favours the management of rainwater in the open air so that maintenance is more easily perennial, and thus a NBS such as a wetland can be put in place.

4.2. Levers to the implementation and the sustainability of NBS

According to the word cloud (Figure 1. B.), the levers for urban NBS are related to projects, roofs, communities, regulations, services, people, etc.

4.2.1. To address the lack of knowledge, research and diagnostic efforts

To respond to the lack of knowledge on NBS, more research is needed. The risks must be diagnosed in details in order to look at the sectors that are in most need of NBS. It could also be interesting to develop *"territorial diagnostic tools, for example, to know where are the risks of flooding or heat waves, to target the different risk levels."* (1) An ecologist cites other avenues of research: *"defining at what scale we speak of NBS, what we group behind it, what is the position of biodiversity in NBS."* (1) To maximise the contribution of biodiversity, more knowledge on species ecology is needed for reproducing favourable conditions for them. It might also be interesting to know the real costs and benefits in monetary terms of NBS in the city. According to a 2016 article by Kabisch et al., the areas of knowledge to be developed were indeed the effectiveness of NBS, as well as the relationship between NBS and society, NBS design, and implementation. There are already several research projects on urban NBS, such as the European Horizon 2020 "REGREEN" project mentioned in the first interview. The main research axes of this project are: improving knowledge about NBS, the development of mapping and modelling tools and the study of the links between well-being, health and nature in cities (Grandin, 2019). There is also the GROOVES study (Green ROOfs Verified Ecosystem Services) carried out by the Regional Biodiversity Agency which was about green roofs in the Paris region. In this study, inventories of flora and fauna were carried out and ecosystem services such as water retention were studied. In general, more weight should be given to NBS studies (Davies and Lafortezza, 2019). To address the lack of indicators on NBS, IUCN has developed a Global Standard with 3 to 5 indicators per criterion in the form of a traffic light (5).

Beyond research, the operational people who set up NBS in cities should make a diagnostic effort, taking into account the context as a whole (local climate, context and coherence). For example, the flora in the vicinity of the NBS that we want to set up could be studied, and possibly put these species into the NBS. One of the ecologists (1) associates this with ecological engineering which should become a reflex when setting up NBS.

4.2.2. A major advantage of NBS compared to traditional solutions is their multifunctionality

"Often, the objective of NBS is to be multi-functional, and therefore not to meet only one environmental challenge. Otherwise, it is not called an NBS. At the very least, it must meet the objectives of adapting to climate change and bringing benefits to biodiversity. If, in addition, it can cool a place or store water, store carbon or be of recreational value to people, it is all for the better." (1) This aspect is of particular importance as the multifunctional aspect of NBS in cities can bring benefits to many fields such as (micro-)climate, ecology, hydrology, socioeconomics, land use planning, architecture, etc. Indeed, NBS can have multiple benefits and help combat many processes such as flooding, heat waves or coastal erosion, etc. (Andersson et al., 2017).

The hydrologist thinks that it is necessary to put forward the multifunctionality of the NBS for promoting them: *"[there is not just one] service but several […]. For example, a pipe handles water better than a green roof, but the roof has more benefits."* (3) He cited many functions delivered by NBS: *"Cooling, fighting against climate change, water management, human well-being, biodiversity conservation, city renaturation, and reconnecting with nature. For water management, an example of advantages is treatment at the source reduction of reject volumes in the networks, maximizing infiltration, minimize runoff in urban surfaces to avoid pollution transfer, limiting impacts on the natural environment."* (3) Other functions provided by NBS in the city such as the case of wetlands, were cited: *"living environment, depollution, shelter for aquatic fauna, maintenance of banks."* (4) The multifunctional aspect of NBS is one of its most important strong points. Per example, in a series of interviews conducted in Australia, 18 of 27 interviewees mentioned this aspect and it was often compared to the single benefit nature of grey infrastructures (Moosavi et al., 2021).

4.2.3. NBS arch across many fields, therefore transdisciplinarity and the establishment of network of actors must be encouraged

As we have seen with the multifunctional aspect, the work on NBS in the city calls for many disciplinary fields. It is therefore essential to promote transdisciplinarity and to create networks between the different stakeholders. *"The importance of transversal governance is that it is very broad and that it associates the locals with the actors of the concerned territory in order to have a common co-constructed project"* (5).

"It is also necessary to make more co-constructions between the actors of the city and actors of biodiversity and of water. Because in fact, we often have projects done separately. We have our vision of things while the people working on the city have their own. Maybe creating a multidisciplinary working group on NBS would be interesting." (1) The fact that professionals from different fields do not have the same ways of thinking refers to "silo thinking" and had already been identified as a barrier to green and blue infrastructure development by O'Donnell et al. (2018).

It is important that actors working on NBS in the city collaborate (Short et al., 2019) and in particular to make the link between operational needs and applied research, or the public and private sectors (Sarabi et al., 2020). Public-private partnerships can even facilitate investments in NBS (Droste et al., 2017). The need for transdisciplinary work, as well as the need to co-design NBS has already been identified as a lever for NBS development (Albert et al., 2019; Nesshöver et al., 2017). Sarabi et al. (2019) even identified stakeholder partnerships as an enabling factor for NBS in 27 papers. There are already collaborations between research and the operational field, such as that of École des Ponts ParisTech and the company SOPREMA, which works on insulation, waterproofing and roofs and offers a wide range of green roofs and facades.

To facilitate transdisciplinarity, it is important that professionals from various fields connect with each other (Sarabi et al., 2020). On the brand "Végétal local" (Végétal local i.e. local vegetation) which sells wild local plants in France, an NBS representative stressed that it would be necessary *"to link the different initiatives like this one and to do everything together, while consulting each other and maintaining a good understanding between each other"* (2). The representative of the Regional Agency for Biodiversity explained her role: *"To act as a link between all the actors, to help local authorities interested in carrying out NBS: they contact me and I guide them for finding technical support or consultancy firms that*

can carry out their field studies; I make sure that there is a follow-up of the projects, encourage them to find funding, and provide the means to carry out these projects. Interface role, lobbying for NBS." (2) Such approaches should be developed in the future for better promoting NBS in the city. This interviewee went on to talk about a European project in which she is involved in, the Life ARTISAN project (Increasing the Resilience of Territories to Climate Change by Encouraging Nature-Based Adaptation Solutions, www.life-artisan.fr). Under ARTISAN and at the national scale, there is a *"resource network consisting of working groups of different themes for the production of resources and tools to support actors on NBS, develop a web interface, provide support for actors, support the mobilization of funding, initiate training programs, and develop studies for buildings indicators needed for the implementation of NBS, etc."* (2) At the regional level, the actors *"decide together to build a roadmap over the next 5 years, and design a strategy for the development of NBS."* (2)

4.2.4. Demonstrator examples that can be replicated

It is important to have good examples to replicate. An ecologist stated: *"I think we need large demonstrators today, such as large wetlands, or experiments like in Lyon, on rue Garibaldi, on the cooling effect of trees, which show us concretely what benefits these NBS bring, and to be able to quantify them."* (1) According to another interviewee, it is necessary *"to bring the elected representatives on the site"* or *"project owners should come and see what is being done"* (6). One NBS project manager summarized it this way: *"You need to have examples, [which is] required by communities. Knowing that another community had the same problem, going to see what they did on their site with an NBS and seeing that it works, makes you want to do the same. [We need to] get the momentum going."* (2) A hydrologist said: *"[We must] manage to show that NBS work, that they are good at absorbing rain, that in places with nature, people are happier and to show that NBS are sustainable"* (3). People likely to uptake NBS need to be reassured. If they see NBS that are functioning properly and providing ecosystem services, they will want to replicate them. For the Life ARTISAN project, in France, there are 10 demonstrator sites, including two in the Ile-de-France region: Les Mureaux and AQUI'Brie, which have been selected on the basis of the NBS project, to demonstrate the implementation of Nature-based Adaptation Solutions. Demonstration sites provide an opportunity to evaluate NBS in practice and adapt their management approach (Kabisch et al., 2016). The European Union has invested heavily in such NBS demonstration projects, notably with the Horizon 2020 research and innovation program (Faivre et al., 2017). Beyond demonstration sites, there are initiatives such as EKLIPSE that aim to evaluate the performance and benefits of NBS (Raymond et al., 2017b).

4.2.5. Climatic hazards can encourage the use of NBS

Although climate can be considered as a constraint for NBS, several interviewees said that they saw it more as an opportunity. Indeed, NBS are often intended to manage the effects of climate change (Hobbie and Grimm, 2020; Seddon et al., 2020). An ecologist declared: *"[the communities] will try to appropriate the subject. [...] if they see that there is flooding, they will want to deal with it", "People are realizing that maybe we should put back trees and vegetation, and that we should maybe restore the river which was buried here a few years ago and so it can act like a sponge."* (1) This sponge notion refers to the "sponge city" concept that was brought forward by the Chinese government in 2013. It *"describes an urban environment that is devoted to finding ecologically suitable alternatives to transform urban infrastructures into green infrastructures so these could capture, control and reuse*

precipitation in a useful, ecologically sound way." (Liu et al., 2017). There are climate-related initiatives such as the Life ARTISAN project discussed above that deal only with climate change adaptation facet of NBS. The fight against climate change may also represent an opportunity to include NBS in the regulations, a point that will be developed later.

4.2.6. What if NBSs could save money?

The ecologist from the Regional Biodiversity Agency had the opportunity to start a study to compare the costs of green infrastructures to those of grey infrastructures. This study could not be completed due to the lack of data, but the preliminary results from a small sample showed that *"green infrastructures, in terms of investment and management, are less expensive than grey infrastructures. For example, underground concrete tanks for rainwater management are much more expensive than systems of swales, ponds or gardens."* (1) A more complete study is needed to confirm these results, but NBS are potentially sources of financial savings. According to Fan et al. (2017), the presence of NBS can even attract investments, while improving the image of the city that houses them. Green spaces that are part of NBS could also help attract knowledge professionals and participate in the city's economic development (Florida, 2005).

4.2.7. Have special funding for NBS

To compensate for the lack of financial means necessary for the development of NBS, one interviewee mentioned several ideas: *"Economic levers to facilitate investments in these NBS, at the community level are important. Perhaps, mechanisms like payments for ecosystem services, or favourable taxation on NBS are a plausible idea. Advantageous loans for communities willing to implemented NBS are also a good idea."* (1) He also referred to the possibility of having funds from the European Commission for the development of NBS or at least for the restoration or the creation of ecosystems. It is in any case very important that public and private funds become developed for NBS in cities (European Commission, 2015). In literature, there are different financial instruments that can encourage NBS, such as the modification of user fees for ecosystem services, limiting impacts on natural areas, and setting fiscal measures (Droste et al., 2017). There may also be grants such as the one given by the European Social Fund to an NGO in Szeged, Hungary, for community gardens (Van der Jagt et al., 2017). There are already initiatives to finance NBS such as "Nature 2050" (Nature 2050, a program designed by CDC Biodiversity) which allows companies to finance NBS, some of which are in cities. The IUCN in its 2018 French NBS committee brochure, indicates other ways to fund NBS, at least in France, such as funding for "climate" projects, "natural risk prevention" projects, calls for projects from Water Agencies, etc. (UICN, 2018).

4.2.8. Labels and certifications that endorse and promote NBS

Labels and certifications can promote NBS in cities by enhancing their value. In this regard, an ecologist expressed his point of view about labels that in his opinion are closest to NBS: *"the BiodiverCity label on buildings. There are Ecojardin, EVE (Espace Végétal Écologique) labels for green spaces […]. Labels are an opportunity for the development of NBS."* (1) The BiodiverCity label, supported by cibi (International Council on Biodiversity and Real Estate), concerns all urbanization projects in urban, peri-urban or natural sites, and displays the performance of real estate projects that take biodiversity into account (Cibi). Two of the goals

set by this label are to "Maximize useful biotopes and ecological functionality" and "Provide nature services for building users" refer to NBS. One interviewee commented on this label: *"BiodiverCity provides a number of criteria to be fulfilled, among which the indigeneity of the plant palette, which obliges to have a certain percentage of indigenous plants"* (9). The EcoQuartier label, for which a person working on was interviewed, is obtained at the urban or rural project level. It includes 4 dimensions: approach and process, living environment and uses, territorial development, environment and climate. Two of these 20 commitments is "Proposing urban planning to anticipate and adapt to climate change and risks" and "Preserve, restore and enhance biodiversity, soils and natural environments". These two commitments can therefore be used to implement NBS in the city. The presence of a green roof on a site can allow obtaining labels such as BiodiverCity, Effinature ("certification devoted entirely to the consideration of biodiversity in construction, renovation and development projects", IRICE) or HQE (High Environmental Quality). But it can also work the other way: wanting one of these labels on a project can push to implement a green roof. It is a priori at the moment, the label BiodiverCity is the one that supports the most biodiversity and NBS in city in French urban projects. However, according to several interviewees, even this label is not demanding enough from an ecological point of view. Experts (e.g. Enzi et al., 2017) agree that other certifications also (BREEAM and LEED) incorporate NBS but not in sufficient detail, particularly with respect to vegetation. It would therefore be necessary to develop the existing labels and to create new ones. A specific label for NBS could beneficial.

4.2.9. Include NBS in the regulations to make their use mandatory and sustainable

Regulations are very important to promote NBS (Sarabi et al., 2020). According to the head of the town planning and natural environment department of the syndicate for hydraulic development, it is even the best lever for setting up NBS in cities. She mentioned the Local Urban Plan (PLU; see Table 2) *"to have more nature in the city. This document allows for clearly defined orientations"* (4). This document has the power to impose NBS in the city. This union also participates in the PLU by working with the municipalities to free up as much space as possible. An ecologist specified on this subject: *"with an urban planning document, one can make a zoning planned, for example for a wetland; one can impose the greening of roofs in the articles of the regulation; one can suggest the management of rainwater on the plot in green spaces; one can suggest vegetated swales in front of buildings. In fact, you can do a lot of things with PLU."* (1) His colleague from the Regional Agency for Biodiversity explained: *"We are trying to introduce the words NBS and measures for NBS in the PLU, PCAET (Territorial Climate-Air-Energy Plan) and in all the planning aspects that we can."* (2) Water management at the parcel level can also be written into the PLU and hence promote NBS. Regarding NBS that affect water management, there are others French documents called SDAGE (Water Development and Management Master Plan) and the SAGE, a variation of the SDAGE at a more local scale of a catchment area and its watercourse. Since 2020, the hydraulic development union has been in charge of integrating the regulations of the SAGE with the *"implementation of protection measures, promoting non-imperviousness around the streets, and the infiltration of the first 8 mm of rain."* (4) Such regulations may encourage the use of NBS for urban water management. The registration of NBS in documents such as the PLU ensures the durability of these solutions, beyond political changes (2). A hydrologist also cited the regulatory constraints by the communities that are in charge of sanitation such as the city of Paris, perhaps also the departments or water management union or water agency, which can be *"either discharge limitation, or an abatement of so many mm of rainfall per event, rather at the scale of a development or combination of several techniques, several NBS"* (3). Such documents can also promote the use of NBS in the city. In

any case, it would be preferable for regulations to take into account the multi-benefit aspect of NBS (Zuniga-Teran et al., 2020).

Acronym	Full name in French	Full name in English	Definitions
PLU(i)	Plan Local d'Urbanisme (intercommunal)	Local (Inter-municipal) Urban Plan	Main urban planning document at municipal or inter-municipal level
PCAET	Plan Climat-Air-Énergie Territorial	Territorial Climate-Air-Energy Plan	A planning tool that aims to mitigate climate change, develop renewable energy and control energy consumption
SDAGE	Schéma Directeur d'Aménagement et de Gestion des Eaux	Water Development and Management Master Plan	Main tool for the implementation of the Community's water policy and set the guidelines for 6 years to achieve the objectives of "good water status"
SAGE	Schéma d'Aménagement de Gestion de l'Eau	Water Management Plan	A more local version of the SDAGE, to reconcile the satisfaction and development of uses and the protection of aquatic environments

Table 2. Names of French regulatory documents cited by interviewees (with their acronyms, full names in French and English, and definitions).

4.2.10. Formation and education on nature and NBS at all levels

To go against the cultural barriers, the director of the hydraulic syndicate explained: *"We are in a logic of training and not of communication, which is not enough to go against these prejudices which have several consequences, as we saw with services of green spaces which completely shave the banks that are under the responsibility of the syndicate. Afterwards, we cannot be surprised that there is erosion on the banks"* (6). One of the ecologists (1) interviewed insisted that elected officials, technical services, schools, communities and private sector individuals need to be trained on NBS issues and ecology in general to become

well aware of these topics and to be able to foster the implementation of NBS. In this dynamic, the director of the hydraulic syndicate talked about a program they initiated: *"an educational program that we introduced this year into riparian schools"* (6). The ecologist (1) also believes that the technical training for engineering firms is needed because he noted that for the majority of ecological compensation measures were badly implemented by engineering offices that lacked the necessary skills. According to this ecologist, landscapers and architects must also be trained in NBS so that they can implement them correctly. Indeed, it would be good if professionals working on urban infrastructure were trained in NBS and not just in grey infrastructure (Davies and Lafortezza, 2019). On this subject, a researcher in ecology warns: *"[We must] rethink the training of public works. Because still some historical lobbying of large groups, of the "all pipe" for stormwater management, of the classic schemes, "all to the sewer", etc. that manage the networks."* (10). None of the interviewees specified whether these education programs should be developed in the pre-service or in-service level, but presumably they need exist at both. Education programs on NBS and related topics at many levels has already been mentioned as a lever for their implementation (Frantzeskaki et al., 2017; Sarabi et al., 2019). Thus, through education, people can be motivated for protecting the environment (Lysack, 2010).

4.2.11. Raising awareness and communication to re-educate on nature and mainstream NBS

According to a water union official, *"It takes a lot of communication, for re-educating people about nature."* (4) *"There is also a need in governance, to have people in human resources in the communities who are in charge of these NBS issues. That this concept is also carried at the national level."* (1) There is a necessity to raise awareness in order to lose the reflex of the classical landscape approach that has subsisted for years and the bad habit of using exotic plants (2). The representative of the Agency of Biodiversity proposed *"to go looking for the communities, to inform them, and to mainstream the term NBS"* (2). To mainstream the concept of NBS, media such as the internet, television, radio, and newspapers can be helpful (Sarabi et al., 2019). It is also important to raise awareness about the effectiveness of NBS (Faivre et al., 2017). To have political and public support, awareness about the links between climate, health, and the benefits of NBS is needed (Santiago, 2016). The responsible of the natural environment of the water union gave another advice to educate the general public toward an increased integration of nature in the city: *"Give yourself stages that would allow the eye to get used to the changes. For example, if you demolish a building, it attracts the eye, but if you remove the floors one by one, then you don't necessarily see that the building is being destroyed. With nature it's kind of the same, by going step by step, it can allow the uninitiated eye to better accept situations gradually rather than shocking it by a single event."* (4)

5. QUANTITATIVE INDICATORS

Based on the previous survey, some indicators have been selected to assess NBS performances and promote their implementation though labels and regulations. These indicators are focussed on the topics studied in the EVNATURB project: stormwater management, urban heat island attenuation and biodiversity reduction. They have to be computed at the parcel scale by the help of the coupled thermo-hydric model (coupling Multi-Hydro and Solene-Microclimat) developed during the project.

5.1. Indicators related to Hydrology

Generally adopted by local authorities in charge of stormwater management, many different regulation rules exist to allow and control the connection to the existing network. They can be

divided in two categories (Petrucci et al., 2013): flow-rate based regulation and volume-based (detention) regulations. Flow-rate based regulation (the most common one) imposes a unique value (often very low and expressed in l/s/ha) of admitted flow-rate from parcels (Balascio et al., 2009 ; Faulkner et al., 1999). They are usually implemented over entire regions, without any consideration for catchments' specificities or hydrographs' superposition. Volume-based regulations prescribe a volume that must be treated at the parcel-scale (expressed in mm of precipitation), without sending it to the sewer network (Mouy et al., 2007). Here is a list of hydrological indicators that can be computed with the coupled thermo-hydric models and that are usually used:

- Flow-rate (l/s/ha): threshold characterizing the maximum discharge flowing out of the parcel outlet
- Detention (mm): rainfall depth which is captured by the NBS
- Stored volume (m^3): total volume of rainwater that can be stored at the parcel scale without reaching the stormwater network
- Infiltrated volume (m^3): total volume of rainwater that can be infiltrated at the parcel scale without reaching the stormwater network
- Runoff coefficient (%): fraction of rainfall fallen at the parcel scale that becomes storm water runoff

5.2. Indicators related to micro-climate

Comfort can be defined as the well-being of a person regarding its surrounding environment conditions. In order to face climate change and the resulting extreme events that should occur more frequently (IPCC, 2014), the question of thermal comfort represents a major issue. It deals with thermal interaction between an individual characterized by its physiology or clothing, and a particular environment characterized by its microclimate (temperature, humidity, wind, radiation…). The heat transfer between both is proportional to temperature difference, but may vary significantly between individuals depending on these previous factors (clothing, humidity, or activity level) for instance.

Outdoor thermal comfort is commonly assessed by only meteorological parameters (wind speed, air temperature and relative humidity) computed with numerical simulations able to capture their high space and high variability (Ragheb et al., 2016). Thermal comfort can be assessed by a simple measure of temperature, but this could be considered insufficient, as interaction with human should be taken into account. Additional and more complex indicators have also been proposed to monitor thermal comfort. They are usually based on the energy balance representing heat exchanges between a person and its environment. The 3 main indicators are the following:

- Predicted Mean Vote (PMV): PMV (Gagge et al., 1971; Shaw, 1972) is widely used in buildings' thermal evaluation. It aims to assess the average thermal feeling of a group of individuals. PEM takes into account both meteorological (wind, air temperature, humidity) and human parameters (metabolism and clothing), and is adjusted based on representative population samples

- Physiological Equivalent Temperature (PET): PET (Höppe, 1993) is the air temperature for which both internal and skin temperatures of an individual are equal in a typical indoor environment. The calculation of PET needs the assessment of some parameters related to physiological conditions (height, weight, age, metabolism, clothing) and indoor environmental conditions (air temperature, wind speed, vapour pressure).

- The Universal Thermal Climate Index (UTCI): UTCI could also be added as it includes the most recent results in thermo-physiological and heat exchange theory (Pappenberger et al, 2015). It depends on the actual values of air and mean radiant temperature (Tr), wind speed (va) and humidity, expressed as water vapour pressure (pa) or relative humidity (rH)

Finally, based on the developed model output and the work done on evapotranspiration evaluation, the following indicators have been selected:

- Evaporated water volume (m^3) or depth (mm): evapotranspiration computed at the urban project scale or at the surface scale

- Air temperature (°C): Air temperature is estimated at an elevation of 2m

- Surface temperature (°C): temperature computed on the building and soil surfaces

- UTCI (°C)

5.3. Indicators related to biodiversity

Traditional indicators used in ecology to assess the quality of biodiversity (abundance and diversity of plant and animal species for instance) are not adapted here as they cannot be computed by the coupled model. So only indicators based on geographical information (layout of NBS patches at the parcel scale) have been conserved.

- Environmental fragmentation index:

- Connectivity indices with existing corridors:

- Percentage of vegetated area (%): percentage of blue and green area at the urban project scale

- Fractal dimension of NBS: It characterizes how much the NBS field - too tortuous to be characterized with the help of the classical Euclidian geometry- fills its embedding space (parcel) not only at a single scale (usually at the maximum resolution), but across the scales.

6. CONCLUSIONS

NBS are considered as efficient tools to develop sustainable cities. For this reason, they are promoted by the UICN and the EU. By conducting several interviews with different professionals working on NBS (of academic, institutional and operational backgrounds), this

study analysed the barriers and levers related to their implementation in France. The lack of scientific and cultural knowledge and the absence of financial, political, and institutional support appear as the main reasons to explain the current low use of these solutions, while the technical problems raised by NBS seem to be more manageable.

To address these issues while putting more emphasis on the conservation of biodiversity, several tracks have been proposed by the interviewees. First, in order to improve the current knowledge on NBS functioning, some significant research efforts should be undertaken. They have to be carried out within a multidisciplinary framework. This seems necessary to better understand and assess the different ecosystem services (regulation, supply, cultural) provided by NBS, as they refer to several different disciplines: ecology, hydrology, mechanics, social sciences, urban planning, microclimate... It is also important to have concrete demonstrative examples of NBS in cities that work well in order to highlight this multifunctional aspect. The follow-up and monitoring of these pilot sites will also contribute to produce quantitative data that will feed research activities.

The second track, which is also deeply related to the development of research, is education. The concept of NBS has to be better and more widely introduced in training programs. The enrichment of knowledge will allow the consolidation of higher education courses and the promotion of their abilities to solve operational problems. The higher education framework will also facilitate the adoption of the multidisciplinary approach mentioned above, and promote the networking of the different actors involved in urban planning. The link between academic knowledge and its operational applications can also be done by certifications and labelling that are commonly adopted by stakeholders. Obtaining a label or certification will eliminate any suspicion of "greenwashing", and also justify the implementation of a NBS rather than a traditional solution. Note that this work has begun with the definition of the IUCN standard. These quantification tools could value NBS performances and also benefit from monitored pilot sites.

NBS are also currently considered as some climate change adaptation tools. On this occasion, they could be recalled NBAS (for Nature-Based Adaptation Solutions). In such an evolving climatic context, the sustainability of their ecosystem services and their associated performances over time is poorly known. This raises many questions about the choice of species to implement, their evolution in an urban environment strongly impacted by climate change, and their possible need for maintenance... Here again, experimentation and the development of knowledge will provide answers that must be taken into account if we do not want to create new barriers to the implementation of NBS.

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