How the concept of nature-based solutions for climate adaptation could be introduced in Master's curricula. Insights from France

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P.-A. Versini [a,*], M. Al Sayah [a], F. Bordignon [b,c], D. Schertzer [a]

[a] *HM&CO, Ecole des Ponts, Marne-la-Vallée, France*
[b] *Ecole des Ponts, Marne-la-Vallée, France*
[c] *LISIS, INRAE, Univ Gustave Eiffel, CNRS, Marne-la-Vallée, France*

ABSTRACT

While the importance of Nature-Based Solutions for climate change adaptation (NBaS) is being increasingly acknowledged, very few studies investigate the status of these solutions in higher education syllabi. In an effort to bridge this gap, this study assessed the position of the NBaS notion in French Master's programs.

Based on a survey questionnaire, several interviews and a text mining analysis of the Master's contents, this paper identified, localised and analysed the French Masters that presented links with NBaS related concepts.

This analysis revealed that the notion of NBaS is far from being mastered. This might be caused by a conceptual misunderstanding of definitions. While text mining revealed that the building blocks of the NBaS framework are present, much still needs to be done for connecting them together. A combined analysis of the findings derived from this study led to recommendations to better introduce NBaS in Masters programs in the future.

Keywords:

Nature-based solutions, Education, Master program, Climate change, Adaptation

1. Introduction

1.1. From nature-based solution (NBS) to nature-based adaptation solution (NBaS)

"Nature-Based Solution" (NBS) is a recent expression characterizing a worldwide practice that uses natural features and processes for increasing resilience to climatological and environmental challenges, while providing environmental, social and economic benefits (Nelson et al., 2020). Still emerging, the NBS term regroups diverse existing terminologies that promote the conservation and rehabilitation of natural ecosystems, namely: Ecosystem-Based Adaptation (EbA), Sustainable Urban Drainage Systems (SuDS), Urban Green Infrastructure (UGI), and others (e.g., Castellanos et al., 2020). Recently, the International Union for Conservation of Nature (IUCN) proposed a global standard to qualify NBS. According to the IUCN, NBS are "*actions to address societal challenges through the protection, sustainable management and*

restoration of ecosystems, benefiting both biodiversity and human well-being" (IUCN, 2020). Previously, and with a focus on urban environment, the European Commission (EC) introduced the NBS concept in its Horizon 2020 Program as "*living solutions inspired and continuously* supported *by nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits*" (European Commission, 2016). These initiatives have clearly promoted the expression in development and rehabilitation projects.

The implementation of NBS in diverse geographical and sociocultural environments has shown their potential for catalysing extensive reframing of classical approaches, and for promoting the integration of eco-system services and infrastructure resilience concepts (UN Water, 2018; Browder et al., 2019). Several works have already illustrated this purpose in agriculture (Peter et al., 2017), urban areas (Babí Almenar et al., 2021; Bush and Doyon, 2019; Raymond et al., 2017), or maritime environments (Arkema et al., 2017; Ruckelshaus et al., 2020). Among the socio-environmental challenges targeted by NBS, climate change is gaining increasing importance. Indeed, for several years, NBS have been promoted as climate change adaptation solutions as they make use of living organisms, soils or landscapes to reduce or mitigate climate change hazards (Kabisch et al., 2017). They have gained prominence both in scientific literature (IUCN French Committee, 2019) and in practical applications, particularly in Europe (Seddon et al., 2019). Several works have already illustrated the importance of developing scientifically-based knowledge on climate change impacts as a precondition for designing and implementing NBS (see Hobbie and Grimm (2020) for the urban environment, or Gomez Martín et al. (2021) for the rural one). Accordingly, the term "Nature-Based adaptation Solution" (NBaS) is currently emerging (Al Sayah et al., 2022), and will be used hereafter in this paper.

It regroups NBS targeting adaptation measures to sea level rise, extreme weather conditions and changes in precipitations, rise in temperatures, food production, health and economic sectors … More recently, NBaS were defined as one of the three cross-cutting priorities in the EU's 2021 strategy on climate change adaptation (European Commission, 2021).

1.2. Sustainable development and education

In parallel to the emergence of the NBaS term, academic teachings and programs devoted to sustainable development have increased during the last decade (O'Byrne et al., 2015; Vermeulen et al., 2014; Withycombe Keeler et al., 2016). This increase can be attributed to the United Nations Decade of Education for Sustainable Development (2004–2014) (Beynaghi et al., 2016). Additional International initiatives have also encouraged the dissemination of this topic in the academic sphere. It is particularly the case of the United Nations Sustainable Development Goals[1] which are a set of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all". SDG 4, "Quality of Education", directly relates to this purpose, specifically under target 4.7 that seeks to ensure knowledge and skills required for the promotion of sustainable development by the year 2030. The large

[1] https://sdgs.un.org/goals.

media coverage of the Conference Of the Parties (COP) 21 and the Paris agreement on Climate Change have also contributed to the widespread inclusion of sustainable development into education programs. The global development of "green job" opportunities can also be considered as a contributing factor (OECD, 2014). In the same manner, more traditional sectors have shown growing interests in sustainable development, as employers are increasingly searching for sustainability expertise within the skill sets of their candidates (Vincent and Focht, 2010).

Therefore, questions about how environment-oriented courses are given appear relevant. This necessity has been revealed and illustrated in several papers (Clark, 2022; Le et al., 2022; Lozano and Barreiro-Gen, 2019; Farinha et al., 2020), where this aspect was usually introduced through the notion of "Education for Sustainable Development". However, very few studies were dedicated specifically on Masters programs (Trencher et al., 2018) and NB(a)S. Indeed, only one paper (Oral, 2022) was focussed on NBS to provide recommendations for increasing ecological education in Turkish higher education institutions. Climate change is introduced more and several papers have focussed on this topic (Hess and Maki, 2019; Milovanovic et al., 2022; Tolppanen et al., 2022). They illustrated that knowledges and practical aspects must be taught together and included within general education curriculum to correct misconceptions and biases related to climate change (Hess and Collins, 2018; Tang, 2022). Understanding the science of climate change appears as a first step towards taking action to address it.

Although the EU and IUCN are pushing NBaS to become a mainstream term, there are no specific studies regarding NBaS and its related concepts are introduced – if introduced – into education programs. It looks particularly important for master's programs, because they usually lead to management jobs. Future graduates will therefore be required to make decisions in land use planning, urban planning, risk and resource management for example. It therefore seems very important that they be made aware of NBS during their studies, as an alternative to traditional "grey" solutions. Moreover, as underlined by recent IPCC (IPCC, 2021) and IPBES (Portner et al., 2021) reports, climate change adaptation and biodiversity conservation/protection must be considered together. Making the bridge between both objectives, NBaS appear to be particularly relevant for this purpose.

Consequently, a comprehensive overview on how NBaS (term and concepts) are being disseminated to students is still lacking. Accordingly, this paper reports insights on the way NBaS are addressed in Master's degrees training programs. It was done in the framework of the LIFE ARTISAN project (Achieving Resiliency by Triggering Implementation of nature-based Solutions for climate Adaptation at a National scale[2]), one of whose objectives is to identify the obstacles and levers related to the implementation of NBaS.

To fulfil its purpose, this research work aimed to identify, localize, and analyse the current Master's level offer in relation with NBaS. This study was conducted in France, as NBaS are trusted to be the way forward for leveraging conjointly the second national climate change adaptation plan (PNACC-2[3]) and the Biodiversity plan[4].It is

[2] www.life-artisan.fr
[3] https://www.ecologie.gouv.fr/adaptation-france-au-changement-climatique
[4] https://www.ecologie.gouv.fr/plan-biodiversite

under this context that the LIFE ARTISAN project aims to promote the implementation of NBaS throughout the French (metropolitan and overseas) territory. Based on the inventoried Master programs, some recommendations were proposed to improve the dissemination of NBaS in higher education curricula, and to promote the uptake of these modules among future graduates.

2. Methodology

The analysis conducted in this study was built using a sequential five stepped approach, mixing open information collection, text-mining analysis and interviews: (i) to inventory all the environmental Masters with a possible link with the NBS, (ii) to design a unified questionnaire and send it to Master supervisors to select those really related to NBS,

(iii) to conduct individual interviews with some of the supervisors to obtain qualitative information, (iv) to analyse Master's contents and descriptions via text mining to highlight similarities and differences, and

(v) to collect and synthetize results to make recommendations.

2.1. Inventory and survey questionnaire

In France, since 2014, Masters are classified by fields and mentions (A mention defines the sectorial, disciplinary and professional approaches of the master program). To select the more appropriate mentions, two databases were used: one developed by the France government, [5] and one created by a media group specializing in information on training, studies and professions for young people.[6] Based on the titles and theoretical contents of the 253 existing mentions, those related to environmental disciplines were selected. It was assumed that they possess possible links with NBaS related concepts. To this end, 13 mentions were selected[7]:

- Biodiversity, Ecology and Evolution (BEE)
- Environment, Energy, Economics and Transport (EEET)
- Risks and Environment (RE)
- City and Urban Environments (VEU)
- Agro-sciences, Environment, Territories, Landscape, Forest (AETPF)
- Geography, Planning, Environment and Development (GAED)
- Urban Planning and Development (UA)
- Environmental Management (GE)
- Water Sciences (SE)
- Land Management and Local Development (GTDL)
- Energy (E)

[5] https://www.trouvermonmaster.gouv.fr

[6] https://www.letudiant.fr/etudes/annuaire-enseignement-superieur/formation/diplome-masters-professionnels.html

[7] Note that Acronyms refer to the French terminologies

- Ocean, Atmospheric and Climate Sciences (SOAC)
- Agriculture, Food and Environmental Sciences and Techniques (STAAE)

A first inventory containing 210 "Environmental" Master was created. For each Master, basic information (location, mention, competences, and courses fields) was compiled from the corresponding website. Then, a survey questionnaire was built in Excel form (Fig. 1) to obtain additional information: objectives, target audience, skills developed, career opportunities, detailed courses, teaching methods, etc. Specific fields were dedicated to NBaS to determine the importance that this notion occupies in the considered course, by whom are they introduced (discipline, specialization, background) and how (in which medium/environment, type, and concepts).

The Master supervisors of these 210 Masters were contacted by email by the authors to complete the questionnaire. In addition to the initial email, two to three reminders were sent a few weeks apart to ensure the highest possible response rate. Additional contacts were created based on the mail feedbacks and the conducted interviews.

2.2. *Interviews*

35 phone interviews were then conducted by the authors with some of the Master supervisors. They aim to obtain additional information about Master's program closely related to NBaS, or provide details to the contacted supervisor to explain the objective of this work and how they can participate. An interviews guide was specially developed for this purpose, and can be found in additional materials. It was organized in 5 groups of questions to: (i) identify of the interviewee and the master program, (ii) assess the interviewee knowledge and activities on NBS,

(iii) understand how NBS is introduced and studied, (iv) have feedback from the direct and indirect beneficiaries of the course, (v) analyse the needs for future development and possible collaboration within the ARTISAN project.

2.3. *Classification*

Following the completion of the first two steps, a two-level classification was made to facilitate the analysis. The first level was related to the strength of the link between the Master's program and NBaS (called "relevancy"). Three categories were then defined according to the importance given to NBaS concepts in the programs' presentation and contents:

- Low: NBaS often named differently are approached in a very marginal way, and the notions of "adaptation" and "climate change" are absent or disconnected. Only one or two courses introduce NBaS, and hence these solutions do not appear as a focal point of the program.
- Middle: NBaS appear in several courses. The link with climate change can be mentioned, without being directly emphasized.
- High: NBaS are mentioned in almost all courses and represent the bulk of the Master's program. Climate change (or global change) is put forward to justify the use of these solutions as adaptation tools.

A second level of classification was proposed based on the environment that the Master's program focused on. This classification was initially proposed by the consortium of the ARTISAN project to be used as a common reference for every action. As masters' programs are usually focused on a particular environment (urban, agricultural, coastal…), the objective was to see if an environment was more familiar to the notion of NBS than another. The following classification was used:

- Natural environment (reserves, park, etc.)
- Agricultural environment
- Forest environment
- Water environments (wetlands, rivers, water bodies, streams, etc.)
- Maritime and coastal environment
- Urban environment
- Mountainous environment
- Multi-environments

It is worthwhile mentioning that the "multi-environments" category was introduced for generalist training programs. The latter offer conceptual or theoretical knowledge rather than a given application in a specific area (e.g. economic training or ecological engineering). In this case, several environments are covered, hence the inclusion of the prefix multi.

2.4. *Text mining: meta-analysis using CorTexT*

A meta-analysis of the inventoried Masters contents was performed using the CorTexT text-mining tool.[8] CorText is a platform for methodological development, software engineering and analytical support for textual corpora. It allows the processing, characterization, analysis and quantification of slightly structured or unstructured textual data. For this purpose, a co-word analysis was conducted on the explored corpus by capturing the frequency of word pairs. When two words are often associated within the same textual element (sentence, paragraph), it means that they are strongly related, hence, these co-occurrences are counted. CorTexT was recently applied for the analysis of scientific literature of different disciplines: permafrost research (Bordignon, 2021), food security (Cardon, 2020), research and education in agroecology (Nicot et al., 2018), and ecoservices in agriculture (Tancoigne et al., 2014).

In this study, the meta-analysis was carried out on the information compiled from the Master inventory, especially for the objectives, skills and courses fields, to understand and characterize the current master offer. This analysis was carried out on the whole sample of environmental Master's degrees (n = 210). Two sub-groups (corpora) were then identified: the first contains all of the inventoried masters that have a more or less strong link with NBaS, identified by the questionnaire returns ("NBaS" group), while the second groups all of the remaining Masters ("Non-NBaS" group).

Once uploaded, CorTexT performs an extraction of terms using the dedicated script available on the tool's platform. Using a distributional measure, CorTexT then automatically groups close terms (e.g., "flood risks" and "risk of flood"). However, the list of terms can also be manually fine-tuned so that synonyms can be grouped

[8] https://www.cortext.net/about-us

together, (e.g., “GIS” and “geographic information system”) or to group any terms that the user considers to be close or associated (e.g., “professional environment” and “professional world”). Irrelevant terms can be then removed (e.g., “training offer”, “various fields”), and others can be added despite their low frequency of occurrence in the corpus (e.g., “nature-based solution”). On this basis, several steps/analysis can follow.

- Similarity and specificity: by determining the number of occurrences for each term, and listing words that are found in the presentation of all Master’s mentions or conversely those that are only found uniquely in one. For that purpose, the skills, objectives or courses sections were investigated.
- Definition of clusters: by representing the network of term co-occurrences (whether they appear in the skills, objectives or courses fields of the survey). CorTexT uses a distributional measure to quantify term co-occurrence (Weeds and Weir, 2005). Within the plotted network, the nodes’ size is proportional to the number of co-occurrences they have with other nodes and is thus highly correlated with their global frequency. Edges between the nodes represent the proximity between terms. The program identifies clusters, which are sets of strongly related terms and represents the topics contained in the corpus (using the same colour in the graph). For each cluster, CorTexT automatically suggests a name that can be changed.

		Comments
Name of the Master program		
University		
Level		
Prerequesite		
Objectives		
Emplyment opportunities		
Key words		5 max
Manager		
Contact		
Website adress		
Courses related to NBAS		
Speakers		
Objectives		
Concerned environment	Autres (à préciser)	
Program		
Pedagological method		
Hourly volume & modalities		
Pedagological documents and tools		
Specific website adress		
Link with NBAS		
General comments		

Fig. 1. A sample of the survey sent to the Master supervisors.

3. Results of the surveys

3.1. Returns and encountered difficulties

Among the 210 solicited Master's supervisors, 118 responded to the survey with answers regarding the link between their training programs and NBaS (either positive or negative). Among the 118 received answers, 68 Masters were finally retained given their different degrees of relationship with NBaS.

It is important to mention that this inventory was built in 2020, at the same time when the COVID-19 pandemic was casting its weight on the world. Under this context, all educational institutions were forced to ensure a pedagogical continuity, by adopting new methods such as remote or distant learning. Naturally, this reduced the availability/ response of Masters' supervisors given their occupation with saving the academic year. Nevertheless, this response rate is clearly higher than that obtained (~10%) for similar approach at the European scale (Lozano and Barreiro-Gen, 2019). To ensure the integrity of this study's inventory, Master's programs whose supervisors did not respond were investigated separately. This was done by analyzing the relationship of their contents with NBaS using their respective websites, description and courses presentation. If these programs were considered unrelated to NBaS, they were excluded from the selection.

3.2. Classification by relevance to NBaS and by environment (or medium)

The classification of Masters by environments is presented in Fig. 2. These findings highlight the predominance of generalist training courses that focus on several environments (i.e. the "multi-environment" category). These Masters are mainly related to ecological engineering and its application in various contexts, whether natural (continental or maritime) or anthropogenic. The urban environment is also the subject of several Masters in connection with NBaS. In most of them, the renaturation of cities and green and blue corridors are particularly promoted. It is worthwhile mentioning that the urban environment is often suitable to multidisciplinary work bringing together hard sciences (hydrology, climatology, mechanics, etc.) and economic and social sciences (urban planning, sociology, law, etc.), hence its widespread presence in syllabi. Conversely, some environments have very few Master programs that are specifically dedicated to them. This is the case of the maritime, mountainous, natural or forest environments. However, despite this small sample, the NBaS concept seems to occupy an important position within these Masters when their programs include adaptation to global changes.

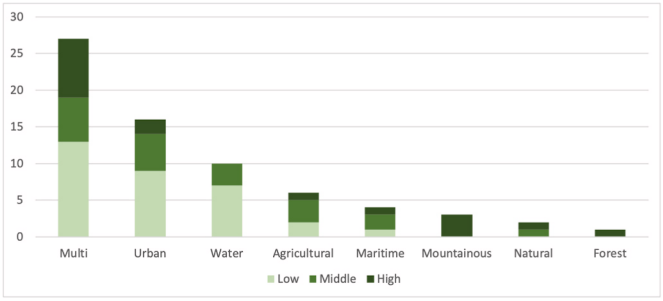

Fig. 2. Inventoried Masters classified by environment and relevancy to NBaS.

The classification by relevance to NBaS (low, moderate and high), revealed that despite the important number of inventoried Masters in the multi and urban environments, only few are significantly relevant to NBaS. These are usually general formations in which the link with NBaS is weak as most of them are classified in the low relevance category. Conversely, the underrepresented environments (Mountainous, Natural, and Forest) refer to Masters in which NBaS appear to have an important role. When climate change impacts are studied in these programs, NBaS are considered as potent solutions for facing these challenges. It should be noted that continental water environments have several Masters inventoried in the low and middle categories, but none in the high. This means that there are no relevant Masters in which NBaS represent the bulk of the program. The usual content deals with resources management or wetlands restoration, without making the link to climate change.

3.3. *Geographical distribution*

In order to geolocalise the selected Master programs on the French territory, an interactive Google Map (https://www.google.com/maps/d/edit?mid=1EyuaacWDe5wY_4mSDfMORXsu0-8DPD1Q&ll=47.235732892962446%2C-0.44982916441731025&z=6) was built. To focus on the most NBaS related Masters, only those belonging to the middle and high relevance categories are shown on this map. For display purposes, the mapped Masters were classified according to their medium of interest (environment), using a specific symbology (Fig. 3). This type of maps allows an evaluation of the program's adequacy with respect to the local geographical context (e.g. a mountain related program in a mountainous area); and can also serve as a decision support tool by helping local actors to identify the Master programs from which they can recruit employees according to their needs.

General Masters targeting multi environments cover the territory in a heterogeneous manner. As can be seen, the North, the Central Region and the Mediterranean coastal areas lack any real trainings in connection with NBaS. On the other hand, one third of the Masters offer is located in the Paris region. Concerning Master programs dedicated to very specific environments, these seem to be derived from their geographical contexts, for instance: courses dedicated to the maritime environment are concentrated near the coastal areas, courses related to the mountainous

environment are located near the mountain belts, and those relevant to water environments are rather concentrated in the inland parts of the country. Urban related NBaS Master programs are particularly concentrated in the north-west of France. Surprisingly, no urban related Masters exist along the Brest-Grenoble diagonal, despite the presence of large metropolises such as Nantes, Bordeaux, Toulouse, and Marseille. Regarding Master programs dedicated to the agricultural sector, these are all located west of the Lille-Marseille axis. This distribution seems logical, given the fact that this part of the territory includes the country's largest useful agricultural area.

4. Results of the meta-analysis

A list of 152 terms was selected for text-mining using CorTexT. Common terms between different Master's mentions (fields) were analysed. The same was done for unique terms that are specific to each field. Tables 1 and 2 illustrate the objectives and courses that are common to the majority of Master mentions included in the NBaS and Non-NBaS corpuses, respectively. Green cells refer to NBaS Masters, red cells to Non-NBaS Masters, while striped cells refer to both. Based on findings from Table 1, the terms climate change, law, policies and regulations appear to be mentioned in many descriptions and objectives of NBaS Masters. However, these are often employed as attracting conceptual elements for positioning the Master mentions into their operational environment, without necessarily having specific teachings on these subjects. This is the case of climate change, where the terms appear to be frequently used but with very little related teaching material. These terms also refer to different scientific domains that seem complementary in an integrated management framework. For this purpose, a multidisciplinary approach is often required. Table 1 also highlights the particularity of certain mentions (E, STAAE) that do not share any objectives with the other mentions of the NBaS corpus (all Masters contained in the EEET and SOAC mentions belong to the Non-NBaS corpus). This is due to the fact that these courses are far from the listed topics, and are oriented more towards biology (STAAE mention) and the energy sectors (E mention).

Fig. 3. Geographical distribution of the NBaS related Masters in France.

Many teachings, tools and methods (statistics, GIS, project management), as well as institutional disciplines (law, public policies and regulations) are selected as common courses of the inventoried Master's programs. They represent a framework to assess solutions and projects from an engineering and political point of view. Within the whole sample, "water" is the only "geophysical" or hard science element addressed in several mentions. This highlights the essential role of this resource regardless of the Master's background. It is also interesting to note that physics, mathematics or biology for instance do not represent common teachings among these environment-related Masters.

Table 3 presents teaching disciplines that are unique to a particular mention. It illustrates that some of the listed courses could directly be linked to NBaS, such as the case of Agroforestry for the AETPF Masters or Landscape management for the RE Masters. This reflects an adaptive orientation geared towards sustainable development both for agricultural and risk management disciplines. Here again, no mention highlights specific teachings in geosciences. They are all majorly characterized by some technical or socio-economical specialities.

Regarding the analysis of the NBaS corpus, 8 clusters were identified by CorTexT and then named based on user interpretation (Fig. 4). Once again, there is no cluster directly related to geoscience. Some fields (hydrology, environmental sciences) are scattered among the different clusters, which are more oriented toward stakeholders and operational management. Adaptation is mentioned, but connected to few items (conservation biology, environmental changes). The most important ones along with their most frequent terms are listed below:

- Tools and systemic approach (*law, GIS, statistical tools and analysis, public policies, climate change*): this cluster regroups courses devoted to tools, methods and disciplines mentioned above and is not specific to NBaS. It should rather be linked to the "Public policies" and "Tools and analysis" clusters found in the Non-NBaS corpus. As already noted, this cluster also refers to the toolbox required to assess solutions and projects from an engineering/political point of view.
- Water management (*Aquatic system, hydrology, resource management, watershed*): This cluster, also present in the Non-NBaS corpus, refers to courses related to water. The latter forms a common theme for many Masters, hence demonstrating the importance of this topic regardless of its field of application (agriculture, risk management, urban environment, etc.). The scarcity of this essential resource, particularly under the intensification of extreme events, may be a reason behind the predominance of the "water" theme.
- Environmental management and impacts (*environmental impacts, environmental management, water, pollution*): this cluster, endowed with numerous connections to the previous one, deals with the threats that ecosystems both natural and anthropogenic have to face. While this cluster is more engineering-oriented, it highlights the importance of monitoring and analysing environmental impacts, for building proper management plans.

Table 1

Common objectives between the different Masters' mentions: Green cells refer to NBaS Masters, red cells to Non-NBaS Masters, striped cells refer to both categories.

	AETPF	BEE	E	EEET	GAED	GE	GTDL	RE	SE	SOAC	STAEE	UA	VEU
Climate change													
Law													
Water													
Environment management													
Resource management													
Policies and regulations													
Natural resources													

Table 2

Common teachings of the Masters' mentions: Green cells refer to NBaS Masters, red cells to Non-NBaS Masters, striped cells refer to both categories.

	AETPF	BEE	E	EEET	GAED	GE	GTDL	RE	SE	SOAC	STAEE	UA	VEU
Law													
Water													
Project management													
Tools and statistical analyses													
Policies and regulations													
Public policies													
GIS													

· Natural resources and environments (*management of natural environments, global changes, environmental sciences, conservation biology*): this cluster, also connects with the previous one, and is more focused on natural environments. It refers more to ecology than engineering. It is also more oriented towards the implementation of solutions. It is in this cluster that NBaS can be introduced. It is also important to mention that this cluster is connected to that of adaptation, hence its importance

(for the "a" in NBaS).

- Regional development and planning (*project management, spatial analysis, territorial development project, urban spaces*): this cluster relates to the territorial scale. It highlights the different spatial scales that must be taken into consideration for implementing a project (*development, management*, etc.), while accounting for the heterogeneity of ecosystems or environments (*urban, natural, agricultural*, etc.).

Regarding the analysis of the Non-NBaS corpus, 7 clusters were defined (Fig. 5). Some of them look similar to those defined for the NBaS corpus, however they are more generic. The most important clusters along with their frequent terms are listed below:

- Public policies (*Policies and regulations, project management, public policies, urban projects*)
- Tools and analysis (*Geographic information systems, statistical tools and analysis, environmental challenges and projects, analysis tools*)
- Water management (*water, hydrology, water treatment, aquatic systems, wetlands*)
- Risk and environmental management (*Law, risk management, environmental management, risks and environments, natural risks*)

Table 3

Teachings unique to a particular mention: Green cells refer to NBaS Masters, red cells to Non-NBaS Masters, striped cells refer to both categories.

	AETPF	BEE	GAED	GE	RE	STAEE	UA
Agroforestry							
Visual sociology							
Urban project							
Stakeholders							
Tools and methods							
Management tools							
Quality management							
Landscape management							
City management							
Social dynamics							
Living conditions							

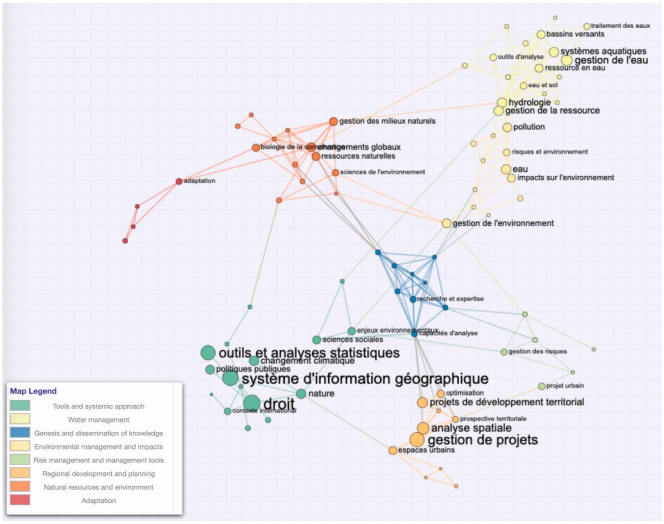

Fig. 4. Clusters identified for the NBaS Masters from text mining analysis.

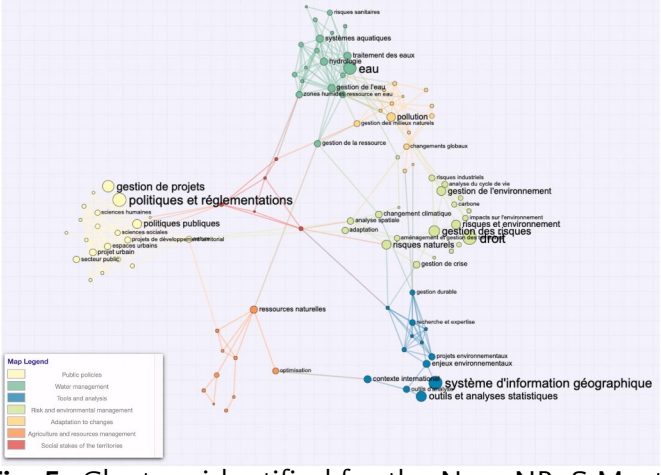

Fig. 5. Clusters identified for the Non-NBaS Masters from text mining analysis.

5. Discussions

5.1. On the NBaS terminology

First of all, it has to be underlined that from the 118 analysed Master's programs, the term "Nature-Based adaptation Solution" is only mentioned once in the courses, descriptions or contents. The analysis of the Masters presentations (via questionnaires and interviews) showed that the term and concepts of NBaS (or simply NBS) are far from being well known and mastered by everyone. Although the IUCN definition, as well as many examples, were recalled in the questionnaire, this terminology had to be redefined and explained to many people. Even when this term

was known, its definition was not perfectly clear. For instance, such comments were made during an interview: “the term NBS so fashionable that it must be employed in all our European proposals is not very explicit in French and is subject to various interpretations”. For others, the NBaS concepts are not “standalone” features, but are rather related to other emerging terminologies (resilience, climate change, etc), which in turn are not well mastered.

In other instances, NBaS were associated with biomimicry or renewable energies concepts. More surprisingly, the concept was sometimes belittled with statements like: “I don’t think we integrate this idea of blah blah solutions”. For others, this concept is embedded in all nature-related activities such as agriculture, regardless of the type of production (intensive or organic).

Indeed, this confirmed that the emerging concept of NBaS encompassed old notions, that are more commonly used based on the field of application or the studied environment. Thus, blue green solutions (or blue green infrastructures) are used in urban hydrology as a tool for storm water management (alternative techniques), “soft solutions” (sand recharging, revegetation) are used in coastal environments, and “agroforestry” practices are used in agricultural media. The concept of “ecological engineering” also often appeared as a synonym for NBaS as both aim to increase the resilience of ecosystems by: promoting the reconstitution of natural environments, restoring degraded environments and optimizing functions provided by ecosystems. Finally, it seems that every university has their own strategies to introduce these notions. Note that similar results were obtained by Farinha et al. (2020) about and Wezel et al. (2018) about agroecology. The Authors attributed this difference to the inner structures/frameworks of the concerned universities.

5.2. Position of the NBaS concept in the master programs

The in-depth analysis of the text-mining results provides further details. Concerning NBaS-related Masters (refer to Fig. 4), the occurrence of the “adaptation” cluster shows that the concept is present to a certain degree. Nonetheless, the size, position and connections of the cluster reveal a relatively shy presence. When considering the NBaS framework, a reference to one or more societal challenges should be made, and an active engagement of stakeholders with various backgrounds must be ensured (IUCN, 2020). As can be seen from Fig. 4, the adaptation cluster is almost entirely disconnected from these societal challenges, as it is only connected to the terms “global changes”, “conservation biology” and “agri-food”, and show no apparent direct links with stakeholders. The concept of adaptation is implicitly present in the Water and Environment clusters, but related to climate impacts related to hydrology (flood and drought). Adaptation to other types of risk (sea level rise, forest fires and dieback for instance) is not mentioned.

While global changes are a relatively vast field, its occurrence in the “natural resources and environment” cluster alone shows that it is being viewed from a narrow angle. Its disconnection from the term “climate change” supports the above-mentioned observation. As the NBaS framework clearly highlights the importance of adapting to global changes, the specificity of the latter should be better addressed. As conservation biology is related to both biodiversity and climate change,

the connection of the term “adaptation” to conservation biology reveals a particular focus on biodiversity. While agri-food clearly relates to food security, the connection between adaptation and agri-food is not sufficient to determine if food security is being holistically studied.

This analysis shows that elements of the NBaS framework are clearly present but are very scattered, often without any multidisciplinary approach. This was confirmed by the questionnaires: NBaS are implicitly mentioned or diffused as marginal ideas in one or more courses. They are usually introduced as case studies where a solution considered as an adaptation measure is presented. Seemingly, workshops and projects related to such case studies are increasingly referring to NBaS.

5.3. Perceptions of NBaS by environment

Named differently throughout the different Master’s programs, the concept of NBS is introduced in a diffuse manner, cited within more general modules or given as an example during lectures, projects, workshops or site visits. Clearly, this inclusion targets the transmission of theoretical knowledge with very few cases of concrete implementation for actual climate change adaptation efforts. Accordingly, the NBaS concept is introduced by environment as follows:

- Multi-environments: ecological engineering is taught for implementing environmental transition tools. The most concerned environments are natural spaces, terrestrial environments, aquatic environments and cities. Biodiversity and landscape integration are put forward for promoting sustainable development based on the “avoid, reduce, compensate” sequence, and thus for counterbalancing negative (degrading) driving forces.
- Urban environment: NBaS concept is presented via the ecosystem services provided by nature in city. Blue green corridors appear as the most mentioned tool. Challenges that are usually addressed are storm water management, urban heat island mitigation and biodiversity conservation.
- Agricultural environment: NBaS concept is introduced through the
- concepts of agroecology and phyto-valorization. These solutions are used for promoting the use of plants as solutions to environmental problems (phyto-purification, restoration of degraded environments, etc.).
- Mountainous environment: Ecological engineering is mostly introduced for the conservation of this medium’s particular biodiversity and hydro systems. Eco-engineering is mainly used to help these environments adapt to anthropization (including agriculture and silviculture).
- Water environment: Courses in these domains mainly focus on the interactions between aquatic environments and landscapes via blue green corridors and biodiversity. Wetland restoration is also often addressed in these courses.
- Maritime environment: NBaS concept is mainly presented through eco-design methods for coastal management related structures.
- Natural environment: the notions of ecology and biology are introduced for focusing on the management, conservation or restoration of natural spaces.

- Forest environment: only one training course related this very specific topic was found. It corresponds to the formation of the Guyana University and targets specifically tropical forests (Guyana). Within this course, conservation biology occupies a considerable volume for adapting forest management to global changes.

5.4. *Is there a "public" demand for NBaS?*

According to the interviewed Masters supervisors, students are asking for more courses that advocate more virtuous solutions for the environment. They seem to be receptive to Nature-Based Solutions when they are presented as examples in projects or workshops. The current emergence of youth political and social movements, such as Youth For Climate [9] favours this shift. However, Masters supervisors also notice that some students have controversial points of views, as they favour grey building solutions over the presence of nature.

According to several Master supervisors, territorial collectivities request that NBaS (appearing under other names) become more integrated into training programs. They consider that young graduates who are aware of these concepts will be in a better position to propose more biodiversity friendly/conservative solutions. This interest is translated by proposals for tutored projects subjects that integrate NBaS for different objectives (wetland restoration, floodplain management, etc.).

Nevertheless, there is no dedicated "environmental engineering" diploma and no specific jobs mentioning explicitly the term of NBaS for now. Therefore, it is important to pursue the creation of new "green" jobs for promoting a dynamic progression towards NBaS both in the education and market sectors. As suggested by several interviewees, the establishment of new regulations that companies can adopt could help. This is particularly important, since to date the absence of regulations related to NBaS severely hampers the development of the concept despite its importance. Once these regulations are created, the "Quality Safety Environment" manager can be in charge of ensuring their implementation. In order to go further on this demand point of view, an additional study could be carried out.

Another path often mentioned for leveraging the use of NBaS, and the emergence of dedicated jobs, is the creation/application of labels and certifications. In fact, according to the Master supervisors, many planners seek to enhance their ecological transition process by obtaining some kind of certification. Some common certifications such as: organic or biodynamic labels for agriculture, or eco-districts for urban neighbourhood, can be more readily obtained using NBaS. As a corollary for obtaining a label or a certification, and to overcome any suspicion of greenwashing, many interviewees highlighted the need for robust evidence on the efficiency of NBaS. Therefore, it seems that there is also a demand for tools and methods that quantify the effectiveness of the planned NBaS.

5.5. *A consensus around the lack of knowledge*

As mentioned above, many interviewees underlined the absence of evidence to

[9] https://youthforclimate.fr

justify the use and dissemination of NBaS. Indeed, from an operational point of view, a quantitative assessment of NBaS eco-system services is required. To implement such a solution, one must be sure to obtain satisfactory results for a particular problem. Behind this quantitative assessment, many disciplines are concerned: physics, biology, hydrology, mechanics, ecology, etc. In these domains, some significant research efforts seem to be required to better understand the NBaS performances over time, and especially under changing climate. These investigations seem necessary to better understand, reproduce and anticipate the behaviour of these NBaS, as well as the physical and biological related processes. Research results, and their applications in terms of decision support tools for instance, should represent relevant material to create new courses devoted to NBaS. These conclusions are corroborated by the absence of hard sciences in the teachings listed in the masters related to the NBS, that are currently dominated by technical or socio-economical topics.

6. Recommendations to update masters programs

Based on the analysis of the results from the text-mining, questionnaires and interviews, some recommendations are proposed to update the Masters programs contents on NBaS issues.

6.1. NbaS: A concept and a term to promote

For unifying the contrasting terminologies that result from different backgrounds or media of interest, the term of Nature-Based (adaptation) Solution should be given further visibility. Little or not known, poorly mastered or outlined with uncertainties, significant pedagogical efforts must be made for familiarizing instructors, students and future employers with NBaS. To overcome this problem of terminology, the concepts behind NBaS should also be better explained. With reference to the IUCN's definition, these concepts include the direct objectives for their implementation: i.e. "*to protect, sustainably manage and restore natural or modified ecosystems"* and the indirect objectives *"while ensuring human good-being and producing benefits for biodiversity*". In order to properly illustrate these purposes, concrete examples of case studies are essential. These case studies must cover the different types of environments (urban, agricultural, forest, water, maritime, etc.) to include the largest audience possible.

6.2. Broaden the range of studied NBaS to underrepresented environments

The inventories of NBaS related Master's programs showed a predominance of general training material, often based on ecological engineering. At the same time, the urban and agricultural media appeared to be the most represented environments, leaving other areas with few or no specific courses. This is particularly the case of the mountainous, forested and maritime environments. Note that similar results on understudied environments were reported for ESD in small islands (Clark, 2022). Therefore, it is necessary to introduce further the concept of NBaS in these areas. This

should be translated by the creation of teaching modules specially dedicated to these environments, based on past or ongoing activities.

6.3. Climate change: a need for deeper insights

Although the term appears in many Masters presentations, very few courses are actually dedicated to climate change, its causes, manifestations, consequences, and how to adapt to it. Climate change appears more as a currently hot topic that describes an ongoing situation and that justifies current legislations. Therefore, climate change should not be treated as a trending idea, but rather should be taught/studied as a complex process. Within its related courses, climate change should be addressed by explaining its genesis and the complexity of the global climatic system. The works of the IPCC should also be presented, namely those related to greenhouse gas emissions scenarios and subsequent consequences on climate and ecosystems. These courses could be locally adapted to the medium of interest (urban, agricultural, etc …), by illustrating the consequences of climate change induced events through concrete examples. Particular attention should also be paid to the uncertainties of climatic models' outputs, and to their difficult spatiotemporal representation of complex phenomena (such as precipitation), (Shepherd et al., 2018; Versini et al., 2016).

6.4. Enlarging the role of geosciences

Throughout the different programs, NBaS are often approached from a biodiversity and landscape approach or agronomy perspective. Usually, given by ecologists, these courses confer an important place to ecology or conservation biology.

Although many of the ecosystem services provided by NBaS are linked to physical or chemical processes (eg. infiltration, retention, evapotranspiration), these are rarely detailed. Therefore, the introduction of geosciences into these courses is necessary for meeting the needs raised by the operational end-users, and reporting quantitative evidence on NBaS efficiency. As already conclude in Oral (2022), the presentation of simulation models could be useful for this purpose. For enforcing the integration of quantitative assessments, the obtention of labels/certifications for Master's programs can also be conditioned by the obligation for robust evidence reporting. To this end, the ARTISAN project also dedicates an action for the formulation of new training modules that can serve the purpose.

Regarding this shift in interest towards geosciences, it is also important to better take into account the complexity of the studied environments across different scales. Spatial scales on one hand, to move from understanding the processes occurring at small scale (soil, vegetation …), to those of infrastructures, and its arrangement in a heterogeneous environment. Temporal scale on the other hand with the variability of the studied processes to consider, given the dynamic nature of climate change and the useful lifetime of the proposed solutions, and the persistence of the NBaS performance over time.

6.5. Towards a multidisciplinary and multi-environmental approach

The dynamic nature and complexity of the environmental, geophysical, biological and social challenges require a transition from silo approaches to multidisciplinary collaborative frameworks.

In fact, certain challenges are common to all kinds of environments despite their differences. This is particularly the case of climate change whose impacts are transversal across different media. The same can be said for urbanization, where urban sprawls expand into different media and create "mosaic" patterns. Given the interconnectivity of the different environments, a silo approach at a scale of a single environment does not fit the real-world conditions. Accordingly, approaches that take into consideration the existing interactions among the different entwined ecosystems are needed.

On this basis, a transformation towards more multidisciplinary training courses should be planned. Nonetheless, this task is not simple, but requires significant collaboration and pedagogical exchanges. However, ensuring multidisciplinary will ensure a transmission of knowledge, and know-hows far beyond the limit of monodisciplinary approaches.

7. **Conclusions and perspectives**

This study assessed the position of the NBaS notion in French Master's programs. It is particularly important as Climate change adaptation and biodiversity protection should be considered together. Students need to be educated and develop some skills in this area.

Based on an inventory, a survey questionnaire, several interviews and a text mining analysis of the Master's contents, this paper identified, located and analysed the French Masters that presented links with NBaS related concepts. The results presented above have revealed that the notion of NBaS along with climate change are far from being mastered. Many gaps have to be filled in to better introduce the concept of NBaS in higher education. Some recommendations have been made to fill these gaps: (i) better explain the concept behind the term of NBaS, (ii) broaden the range of studied NBaS to underrepresented environments (mountainous, maritime), (iii) improve knowledge on climate change consequences, impacts and mitigation measures, (iv) put more focus on geosciences, (v) promote a multi-disciplinary and multi-environmental approach.

This work could help to move forward to promote a better integration of NBaS in the Masters programs in the future. As the UNFCCC states, adaptation is an iterative, progressive and dynamic process. Therefore, progress can only happen by learning. Accordingly, stimulating formal and particularly higher education curricula to integrate more adaptation solutions, here NBaS, can contribute to progress towards adaptation.

CRediT authorship contribution statement

P.-A. Versini: Supervision, Conceptualization, Writing – original draft, Writing – review & editing, Visualization. **M. Al Sayah:** Writing – review & editing, Formal analysis. **F. Bordignon:** Writing – review & editing, Formal analysis, Software, Visualization. **D. Schertzer:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.136364.

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