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Nature-based solutions: set of practices, scientific theory or transformation movement?

Soluções baseadas na natureza: conjunto de práticas, teoria científica ou movimento de transformação?

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ABSTRACT: The expression "Nature-based Solutions" (NbS) has been present in academic and political discourses since 2008, when it was first mentioned. However, like any new expression, its application has been diverse, thus generating confusion about what NbS are. In this article, through a systematic review it was sought to understand what NbS are, from three perspectives: a set of practices, a scientific approach, and a transformational movement. Although different, these perspectives proved to be complementary in understanding what NbS are. As a result, an integrative definition of these three perspectives is presented, in which the NbS are defined as practical actions, scientific theory and transformation movement aimed at studying, proposing and applying sustainable solution strategies for socio-environmental problems, based on understanding the functioning of balanced social and ecological systems and on re-signifying the relationship between humans and nature.

Keywords: Nature-based Solutions; green infrastructure; human-nature relationship; sustainable solutions; social and ecological systems.

RESUMO: A expressão Soluções baseadas na Natureza (SbN) vem ocupando espaço nos discursos acadêmicos e políticos desde 2008, quando foi pela primeira vez mencionada. Porém, como toda nova expressão, sua aplicação tem

sido diversa, gerando assim confusão sobre o que de fato são SbN. Neste artigo, através de uma revisão sistemática, buscou-se compreender o que são as SbN, a partir de três perspectivas: conjunto de práticas, abordagem científica e movimento de transformação. Perspectivas que, embora diferentes, mostraram-se complementares na compreensão do que são as SbN. Como resultado, apresenta-se uma definição integradora dessas três perspectivas, na qual se define as SbN como sendo ações práticas, teoria científica e movimento de transformação que têm por objetivo o estudo, proposição e aplicação de estratégias de solução sustentáveis aos problemas socioambientais, a partir da compreensão do funcionamento de sistemas sociais e ecológicos equilibrados e ressignificação da relação homem-natureza.

Palavras-chave: Soluções baseadas na Natureza; infraestrutura verde; relação homem-natureza; soluções sustentáveis; sistemas sociais e ecológicos.

1. Introduction

The expression "Nature based Solutions", or Nature-based Solutions (NbS), was used for the first time in 2008 in a World Bank publication entitled "*Biodiversity, Climate Change and Adaptation*: *Nature-based solutions from the World Bank Portfolio*" (Ruangpan *et al*., 2020). While not explicitly defining the expression, this publication alludes to the concept of solutions grounded on the conservation and sustainable use of ecosystems and biodiversity to alleviate global poverty and address climate change (Mackinnon *et al*., 2008).

Although the expression is relatively recent, some of the approaches related to it are not. Escobedo *et al*. (2019) and Ruangpan *et al*. (2020) refer to these approaches as "sister concepts" and "metaphors", respectively. The sister concepts presented by Ruangpan *et al*. (2020) are all related to the reduction of hydrometeorological risks, as the review conducted by the authors focuses on the following areas: "low-impact developments" (appeared in 1977), "best management practices" (1980), "water-sensitive urban design" (1994), "green infrastructure" (1995), "sustainable urban drainage systems" (2001), "ecosystem-based adaptation" (2009), "ecosystem-based disaster risk reduction" (2010) and "blue-green infrastructure" (2013). The metaphors mentioned by Escobedo *et al*. (2019), also in chronological order of emergence, are "urban forests" (17th to 20th century), "ecosystem services" (more widely used after publication of the Millennium Ecosystem Assessment in 2005), and "green infrastructure".

Kabisch *et al*. (2016) refer to NbS as one of many concepts that promote maintenance, improvement and restoration of biodiversity and ecosystems as a means of simultaneously dealing with several problems, such as "ecosystem-based adaptation", "green infrastructure", "ecosystem-based disaster risk reduction" and "natural water retention measures". In doing so, Kabisch *et al*. (2016) place NbS as part of a group of concepts that have overlaps. Lafortezza *et al*. (2018) do the same by presenting concepts that the authors refer to as "very close" to NbS, namely: "sustainability", "resilience", "human and environment coupled", "ecosystem services" and "green (blue) infrastructure". However, they refer to these last two and to "ecosystem-based adaptation" as NbS subgroups. Lafortezza *et al*. (2018) place NbS as an "umbrella concept". Within this same perspective, Nesshöver *et al*. (2017) assert that there are diversifications of the term NbS, such as "nature-based infrastructure" and "engineering

with nature" and present concepts that are related to or have overlaps with NbS, namely: "ecological engineering and harvesting systems engineering", "green/blue infrastructure", "ecosystem approach", "ecosystem-based adaptation/mitigation", "approach/structure of ecosystem services" and "natural capital".

There are also those who mention NbS as a concept (Kabisch *et al*. 2016; Faivre *et al*., 2017). The meaning of the word and its synonyms in the English language (concept, idea, notion, vision, theory, etc.) are too vague to understand something in its essence. There are also those who refer to NbS as a "framework" and "approach" (Panno *et al*., 2017), as a "term" (Albert *et al*., 2019; Ruangpan *et al*., 2020), or even as a "transition" (Maes & Jacob, 2017). However, an even more extensive list of authors define NbS as solutions or actions (Liquete *et al*., 2016; Nesshöver *et al*, 2017; Maes & Jacobs, 2017; Faivre *et al*. 2017; Kabisch *et al*., 2017; Van den Bosch & Ode Sang, 2017; Fan, 2017; Kabisch *et al*., 2017; Van den Bosc & Ode Sang, 2017; Short *et al*., 2018; Albert *et al*., 2019; Cohenhacham *et al*., 2019; Frantzeskaki, 2019; Short *et al*., 2019; Ruangpan *et al*., 2020).

All these ways in which NbS have been called and treated can create confusion about what NbS actually entail. In this context, this article aims at providing an understanding of what Nature-based Solutions are through a systematic literature review, involving partial reading of 100 articles and full reading and discussion of 30 articles. This understanding goes beyond mere concepts, encompassing their uses and applications.

2. Methods and procedures

This article is a systematic literature review based on domain, according to the classification proposed by Paul and Criado (2020). For its development, we adopted a systematic selection method for data collection and analysis, which is described below.

2.1. Data collection

As data collection sources (document retrieval), we used the Web of Science and Scopus databases, which enable exporting document settings in CSV format for bibliometric analyses through the Vosviewer software. We focused on documents containing the term "Nature-based Solutions" in their title. Table 1 presents the results of the initial search carried out in five different databases. Only Web of Science, Scopus and Google Scholar presented results pertinent for the research. However, only Web of Science and Scopus allowed exporting article settings in CSV format for bibliometric analyses using the Vosviewer software.

Consequently, the 100 most cited articles in Web of Science and Scopus were selected, focusing on those that covered the most commonly addressed topics in NbS. After reviewing the titles, abstracts and keywords, 30 articles were selected for full-reading and discussion. The procedure consisted of the following steps:

Step 1 (Search 1): conducting a search with the selection criteria of articles (excluding other types of documents) containing the term "Nature--based Solutions" in their title. This resulted in 212

TABLE 1 - Result of the search carried out in five different databases for all types of documents that had the term "Nature-based Solutions" in their title. Only Web of Science, Scopus and Google Scholar presented results. However, Google Scholar does not allow exporting article settings in CSV format for bibliometric analyses using the Vosviewer software. Therefore, it was excluded from the analysis.

Language	**Databases**				
	Web of Science	Scopus	SciELO	Redalyc	Google Scholar
Portuguese	1	0	0	0	10
English	248	260	0	0	812
Italian	2	5	0	0	1
Spanish	0	2	0	0	24
Chinese	2	1	0	0	12
French	0	1	0	0	2
Not identified	N/A	2	N/A	N/A	N/A
Russian	3	0	0	0	N/A
TOTAL	**256**	**271**	**0**	**0**	**861**
COLLECTION DATE	**02/16/2021**	**02/10/2021**	**02/16/2021**	**02/16/2021**	**02/16/2021**

SOURCE: the authors

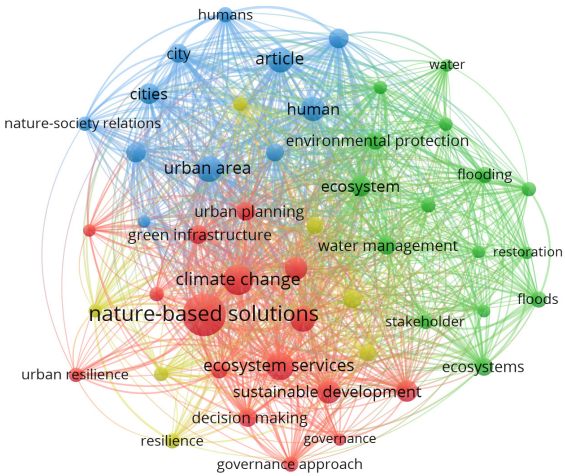
and 200 documents in Scopus and Web of Science, respectively.

Step 2 (Bibliometric analysis): using all the information exported from both databases, a bibliometric analysis of keywords was conducted using Vosviewer, where it was possible to create four clusters in Scopus and three clusters in the Web of Science. For each of these clusters, the keywords with the highest occurrence and links to other words were selected (Figure 1 and Annexes A to D). This procedure was adopted to perform a new search that would yield articles on NbS discussing the most relevant topics associated with the expression.

Step 3 (Search 2): a new search was conducted in the databases. "Nature-based Solutions" in the article title was used as a criterion and, in all other fields of search, the keywords from each cluster were used as an additional criterion. These were separated by the "*OR*" Boolean operator. The search was refined to articles and reviews only. As a result, 196 and 334 articles were obtained with repetitions in Scopus and Web of Science, respectively (Annex E). From these articles, we selected the 100 most cited articles from both databases, representing groups A and B of articles, as shown in Figures 2 and 3.

Step 4 (Exclusion of duplicates): all repeated articles from the total of 200 were excluded. Subsequently, the 100 most cited articles from both databases were selected (Group C – Figure 3), taking into account the participation of all clusters in assembling this sample of articles for reading the titles, abstracts and keywords. For these articles, in addition to reading, relevant information from the materials was also summarized (Annex F).

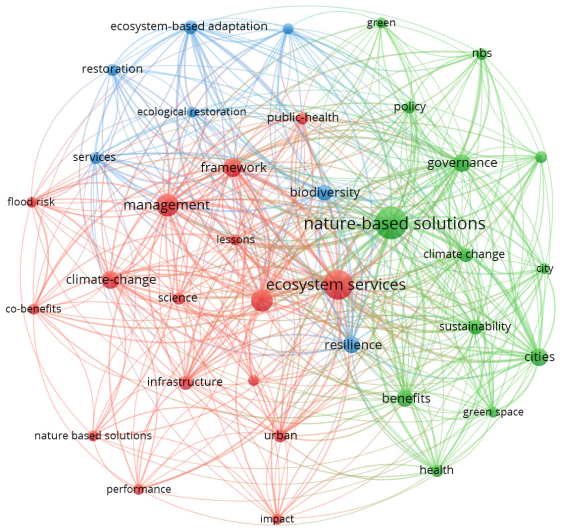
a



b

Database: Scopus			
Cluster	Keyword	Occurrence	Total strength of the links
Green	Climate change	45	263
	Ecosystem Service	32	231
	Ecosystem Services	37	208
Blue	Urban area	33	226
	Human	28	180
	Humans	12	100
Red	Water management	17	96
	Flood	13	69
	Flooding	13	81
Yellow	Adaptive management	17	124
	Risk Assessment	14	77

c



d

Database: Web of Science			
Cluster	Keyword	Occurrence	Total strength of the links
Green	Climate change	14	65
	Climate-change	23	69
	governance	23	117
	Cities	22	100
	City	9	38
Blue	Biodiversity	17	81
	resilience	19	86
	Ecosystem-based adaptation	13	77
Red	Ecosystem service	59	219
	Green infrastructure	32	132
	Management	35	142

FIGURE 1 – Network visualization of keywords with the highest occurrence and links. Figures 1a and 1c represent, respectively, the network visualization displayed by Vosviewer to show the most cited keywords in the universe of articles with "NbS" in their title, as well as the links they have with other keywords in Scopus and Web of Science. Next to the figures are the occurrence values of the words and the connection strength. Keywords are represented by nodes, and their size is proportional to their importance in the context of the review. Larger nodes indicate greater relevance and frequency of occurrence in the studies, whereas smaller nodes have less relevance or appear less frequently. Connections between nodes are illustrated by lines, and their thickness represents the association strength. The thicker the line, the higher the frequency with which the keywords occur together in the studies reviewed.

SOURCE: the authors.

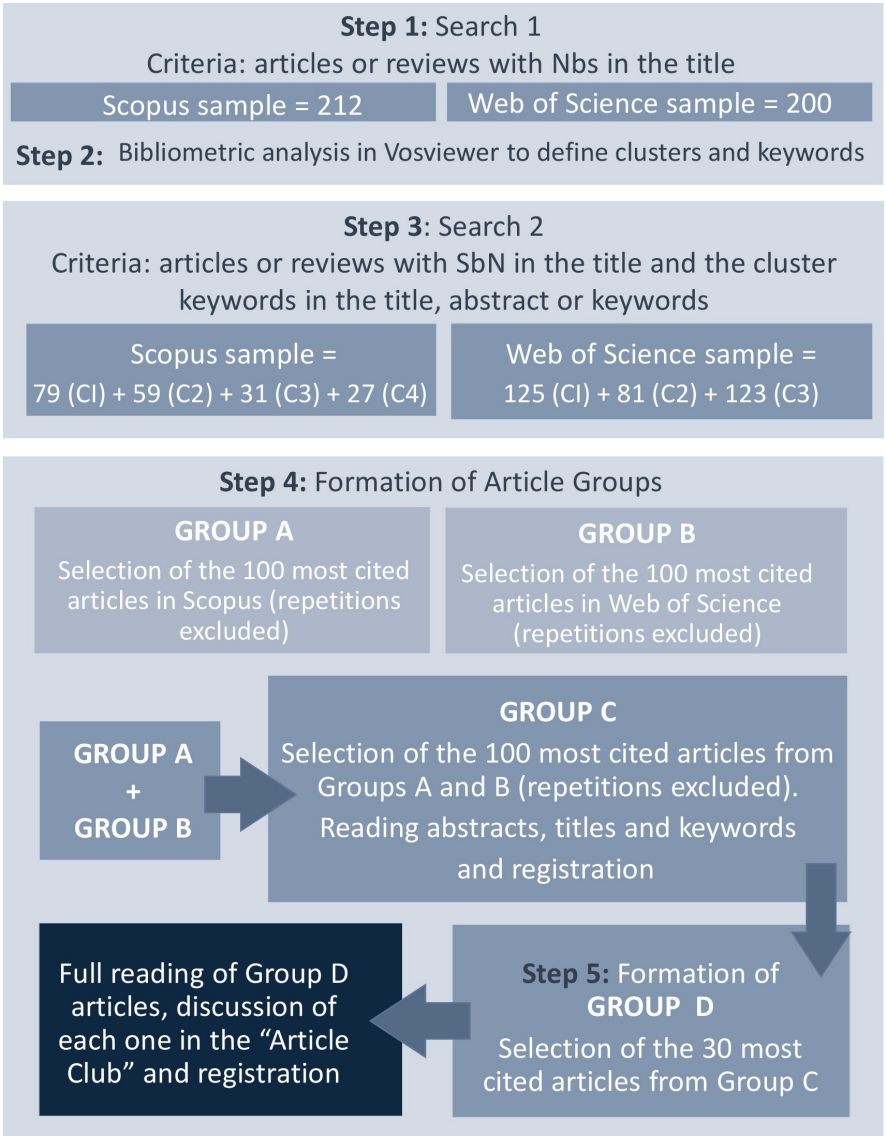


FIGURE 2 – Step-by-step data collection. Step 1: Search 1 - Searching for articles with the term NbS in their title, in the Scopus and Web of Science databases; Step 2: Network analysis of keywords using Vosviewer; Step 3: Search 2 - Searching for articles with "NbS" in their title and at least one of the strongest keywords from each cluster obtained through the Vosviewer network analysis, included in the title, abstract or keywords fields, in both databases (formation of groups A and B of articles). Step 4: Selection of the 100 most cited articles from groups A and B, and exclusion of repeated articles (formation of Group C of articles). Step 5: Selection of the 30 most cited articles from Group C, with participation of all clusters (formation of Group D of articles). NbS: Nature-based Solutions; C1 = Cluster 1; C2 = Cluster 2; C3 = Cluster 3; C4 = Cluster 4.

SOURCE: the authors.

Step 5 (Selection of articles for full-reading): of the 100 articles resulting from the previous step, the 30 most cited ones (Group D) were selected, ensuring representation from all clusters. These articles were read and registered by two of the co-authors, as suggested in Paul and Criado (2020). With the full-reading, the relevant information summarization was expanded (Annex G).

Figures 2 and 3 summarize the steps of the data collection process.

2.2. Data analysis

In addition to being summarized, the articles were discussed in what was referred to as the "NbS Article Club". Following the discussions within the Article Club, drawing inspiration from Silici (2014), it was noticed that there was a need to analyze Nature-based Solutions from three different perspectives: practice, science, and movement, in order to answer the overarching question guiding this research: What are Nature-based Solutions?

We start from the concept attributed by the authors of our sample, or adopted by them. For the analysis of NbS as a science, we employed the theoretical framework proposed by Lakatos and Marconi (1992), Pombo *et al*. (1994) and Funtowicz and Ravetz (1997). To analyze NbS as a transformation movement, we used Moore *et al*. (2014).

3. Results and discussion

To present the results and discuss them clearly, we divided this section into three subsections aimed at orderly answering the following:

i) Are NbS a set of practices?;

ii) Are NbS a scientific theory?; and

iii) Are NbS a transformation movement of social and ecological systems?

3.1. Are NbS a set of practices?

Among the various ways in which NbS are treated in our sample, the most common is understanding that NbS constitute a set of practices. By set of practices we refer to actions, activities, operations and practical work carried out or proposed following specific procedures and using certain tools to achieve predefined objectives and goals.

At some point in their texts, the thirty authors belonging to Group D of articles refer to NbS as an action, solution, intervention or measure, words that convey the idea of NbS as a set of practices (Table 2). Among the concepts that convey this understanding, the most frequently cited by the authors in our sample (Annex G) are the concepts presented by the European Commission (2015) and by Cohen-Shacham *et al*. (2016). According to Cohen-Shacham *et al*. (2016), citing the International Union for the Conservation of Nature (IUCN), NbS are "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges (for example: climate changes, food and water security or natural disasters) effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". This concept is in line with the definition presented by the European Commission (2015), which refers to NbS as actions inspired, supported or copied from nature that aim at helping societies sustainably address a range of environmental, social and economic challenges.

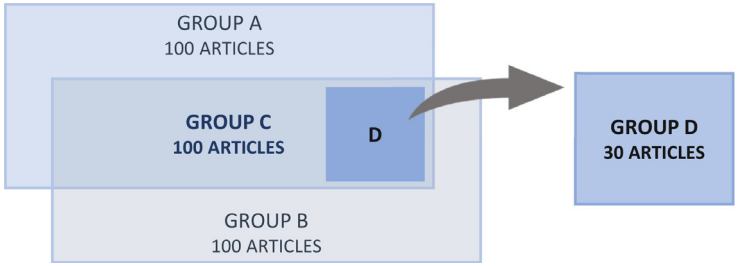


FIGURE 3 – Samples: Group C (100 articles) and Group D (30 articles). Formation of Group D of articles (articles read in full, discussed and summarized) as a subset of Group C (articles with title, abstract and keywords read and summarized), which, in turn, is comprised by articles from groups A and B.

SOURCE: the authors.

Among the actions that qualify as NbS, the authors in our sample mention the following, for example (Table 2): creation of new spaces for rivers, a solution known as "*room for river*" (Santoro *et al*., 2009; Keesstra *et al*., 2018; Lafortezza & Sanesi, 2019); organic agricultural production (Keesstra *et al*., 2018) and agroecological farming (Maes & Jacobs, 2017); agroforestry (Keesstra *et al*., 2018); creation of blue or green structures (Liquete *et al*., 2016; Wild *et al*., 2017; Kabisch *et al*., 2017; Keesstra *et al*., 2018); construction of green walls or roofs (Kabisch *et al*., 2016; Raymond *et al*., 2017; Faivre *et al*., 2017; Fan *et al*., 2017; Zölch *et al*., 2017; Xing *et al*., 2017; Gulsrud *et al*., 2018; Lafortezza *et al*., 2018; Frantzeskaki *et al*., 2019; Ruangpan *et al*., 2020); tree planting in urban areas (Kabisch *et al*., 2016; Faivre *et al*., 2017; Zölch *et al*., 2017; Escobedo *et al*., 2019; Lafortezza & Sanesi, 2019), creation of urban gardens (Raymond *et al*., 2017; Faivre *et al*., 2017; Fan *et al*., 2017; Van der Jagt. *et al*., 2017; Lafortezza *et al*., 2018; Frantzeskaki, 2019); conservation, restoration or creation of wetlands (Liquete *et al*., 2016; Nesshover *et al*. 2017; Thorslund *et al*., 2017; Van den Bosch & Ode Sang, 2017; Fan *et al*., 2017; Escobedo *et al*., 2019; Albert *et al*., 2019; Santoro *et al*., 2019); maintenance and restoration of permeable soils (Lafortezza *et al*., 2018); creation of green parks (Kabisch *et al*., 2016; Liquete *et al*., 2016; Faivre *et al*., 2017; Van den Bosch & Ode Sang, 2017; Fan *et al*., 2017; Wild *et al*., 2017; Escobedo *et al*., 2019); conservation, management and restoration of forests (Santoro *et al*., 2009; Van den Bosch & Ode Sang, 2017; Wild *et al*., 2017; Lafortezza *et al*.; 2018; Escobedo *et al*., 2019); and creation, conservation and restoration of lakes (Santoro *et al*., 2009; Liquete *et al*., 2016; Nesshover, *et al*., 2017; Short *et al*., 2018; Frantzeskaki, 2019; Ruangpan *et al*., 2020).

Each action has determined procedures and objectives. Let us briefly examine three case studies from our sample that involve horticulture therapy, the use of Large Woody Debris (LWD) in channels and floodplains, and green roofs and tree pits on street planting (Table 3). By analyzing these three case studies, it is possible to perceive aspects of the NbS practice.

In the first case study, Vujcic *et al*. (2017) analyzed the application of horticulture therapy, an NbS, for the treatment of patients with depression,

anxiety and stress. The treatment aimed at improving the mental health and well-being of patients in urban areas. The sessions included plant activities, art therapy and relaxation sessions. As a result, reductions in depression, anxiety and stress were observed in the patients. An increase in group social support and enhancement of the participants' creativity were identified as co-benefits. Additionally, the authors mention that horticulture therapy is a cost-efficient activity when compared to conventional treatments.

Short *et al*. (2018) analyzed the application of an NbS suite in Costwold, England. Among them, the authors refer to Large Wood Debris (LWD) (Table 3), which are logs from trees or main branches of native plant species deposited along the entire river channel. The purpose is to slow down the water flow during flooding events, creating flow attenuation and/or diverting the water to preferred storage areas. As a result, a reduction in the water level of the rivers and the peak of floods was noticed. The following were identified as benefits: increased commitment and knowledge of the local population regarding the problem; reduction of property damage due to floods; improvement of the environmental and ecological conditions of the watershed; and decrease in the environmental impacts associated with gray solutions. By gray solutions we mean those traditional engineering solutions that oftentimes involve extensive use of manufactured raw materials, frequently made of concrete. Additionally, the authors state that NbS are more efficient in financial terms when compared to gray solutions.

Finally, we have the case study analyzed by Zolch *et al*. (2017), who compare different scenarios using, either alone or in combination, two NbS: green roofs and trees in pits planted in street corners in an urban area region of city from Munich, Germany. The research aimed at analyzing the best composition with regard to the objective of applying these NbS: regulation of urban surface runoff. According to the authors, after analyzing different scenarios (1 – Current scenario, 2 – Combinations of green roofs and street tree planting, 3 – Green roofs only, 4 – Street tree planting only), they concluded that, with a combination of green roofs and street tree planting with 53% vegetation coverage, it is possible to reduce surface runoff by up to 14.8%. The authors do not mention whether NbS are cost-efficient[1] in this case.

With the three examples presented, it is possible to perceive the practical nature of NbS. In general, they consist of practices aimed at assisting humans in addressing socio-environmental challenges. Faivre *et al*. (2017) emphasize that, in the implementation of NbS, biodiversity conservation is not only a prerequisite for humans to address socio-environmental challenges, as functioning ecosystems are necessary to ensure the generation of ecosystem services, but it is also one of the goals of NbS themselves. Here, the ecological categorical imperative is perceived, which, according to Proops (1987), leads humans to care for nature as a moral obligation. Therefore, reducing biodiversity loss is also a challenge faced by current societies.

[1] *Cost-efficient:* term used to refer to actions understood as of low cost and high efficiency when compared to alternative actions.

TABLE 2 – Group D of articles: main information.

No.	Author(s) (Year) Title	Nature-based Solutions (Adopted or mentioned)	Problem at which the solution is aimed	How NbS are referred to
1	Keesstra, S. *et al* (2018) *The superior effect of nature-based solutions in land management for enhancing ecosystem services*	Landfill, creation of new area for the river, organic farming, rewilding, agroforestry, grass strips and soil or stone bunds, blue-green infrastructure.	Land and water management	Practice
2	Kabisch, N. *et al*. (2016) *Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action*		Climate-change mitigation and adaptation	Theory and Practice
3	Nesshover, C. *et al*. (2017) *The science, policy and practice of nature-based solutions: An interdisciplinary perspective*	Ponds, wetlands, and leaky barriers.	N.S.*	Practice
4	Raymond, C. M. *et al*. (2017) *A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas*	Roof-greening, solar roofs, urban food gardens, water reticulation systems.	Climate resilience, health and well-being.	Practice
5	Maes, J.; Jacobs, S. (2017) *Nature-Based Solutions for Europe's Sustainable Development*	Agroecology	*Trade-offs between economic growth and sustainability.*	Movement and Practice
6	Faivre, N. *et al*. (2017) *Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges*	Pocket parks, urban agriculture, street trees, green roofs, community garden, natural water retention, sustainable urban drainage, biosequestration, afforestation, green corridors, natural coastal protection (semi-fixed dunes) floodplain restoration.	Social, economic and environmental challenges (jobs and growth, energy and climate action).	Theory, Movement and Practice

7	Liquete, C. *et al*. (2016) *Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits*	Wetlands surrounded by green areas (parks).	Water pollution control.	Practice and Movement
8	Thorslund, J. *et al*. (2017) *Wetlands as large-scale nature-based solutions: Status and challenges for research, engineering and management*	Wetlands.	Carbon sequestration, water quality protection, coastal protection, groundwater level, soil moisture regulation, flood regulation and biodiversity support.	Theory and Practice
9	Morris, R. L *et al*. (2018) *From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence*	Restored or created coral reefs, dunes, macroalgae, mangrove, oyster reef, saltmarsh, and seagrass.	Erosion and flooding along coastlines.	Practice
10	Escobedo, F. *et al*. (2019) *Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors?*	Urban trees/forests (treed parks, wetlands), forest, trees, and vegetation.	Urban problems.	Movement and Practice
11	Zölch, T. *et al*. (2017) *Regulating urban surface runoff through nature-based solutions – An assessment at the micro-scale*	Urban green infrastructure (trees and green roofs).	Urban surface runoff.	Practice
12	Lafortezza, R. *et al*. (2018) *Nature-based solutions for resilient landscapes and cities*	Urban agriculture for local food production and social cohesion; green roofs for climate adaptation; regeneration of abandoned industrial land by afforestation or park creation; rain gardens for stormwater regulation; green spaces for promoting human health; the use of permeable surfaces and vegetation in urban settings.	Urban problems.	Practice

13	Panno, A. *et al*. (2017) *Nature-based solutions to promote human resilience and wellbeing in cities during increasingly hot summers*	Urban green area (park).	Urban heat island.	Practice
14	Xing, Y.; Jones, P.; Donnison, I. (2017) *Characterisation of nature-based solutions for the built environment*	Indoor plants, green roofs, green walls, green & blue landscaping.	Pressures on the natural environment due to rapid urbanization.	Practice
15	Gulsrud, N. M.; Hertzog, K.; Shears, I. (2018) *Innovative urban forestry governance in Melbourne?: Investigating "green placemaking" as a nature-based solution*	Urban green infrastructure (green roofs, walls, and facades).	Climate change and ecological gentrification.	Practice and Movement
16	Albert, C. *et al*. (2019) *Addressing societal challenges through nature-based solutions: How can landscape planning and governance research contribute?*	Revitalizing floodplains, protecting and establishing wetlands, and better adapting land-uses to site conditions within the watershed.	Social challenges.	Practice
17	Bosch, M.; O de Sang, Å. (2017) *Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews*	Green places like parks, ecosystem restoration, greening of gray surfaces, afforestation, natural flood control, and constructed wetlands.	Human health and well-being.	Practice
18	Kabisch, N.; Van den Bosch, M.; Lafortezza, R. (2017) *The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review*	Urban green and blue spaces.	Children and elderly health.	Practice
19	Vujcic, M. *et al*. (2017) *Nature based solution for improving mental health and well-being in urban areas*	Horticulture therapy.	Mental health and well-being in urban areas.	Practice

20	Frantzeskaki, N. (2019) Seven lessons for planning nature-based solutions in cities	Constructed wetland, urban agriculture, bioremediation ponds; pocket park, linear park, green waterfront; urban park; Urban agriculture, green roofs; linear urban waterfront park; bioswells, raingardens, nature-based playgrounds; and nature-based playground.	N.S.	Practice
21	Song, Y. *et al*. (2019) *Nature based solutions for contaminated land remediation and brownfield redevelopment in cities: A review*	Phytoremediation, constructed wetland, bioremediation, green synthesis for nanoremediation and stabilization with biochar, mulch and compost.	Soil and water of brownfields.	Theory and Practice
22	Cohen-Shacham, E. *et al*. (2019) Core principles for successfully implementing and upscaling Nature-based Solutions	N.A.**	N.S.	Theory and Practice
23	Fan, P. *et al*. (2017) *Nature-based solutions for urban landscapes under post-industrialization and globalization: Barcelona versus Shanghai*	Parks, refurbishing old parks, forest parks, creation of a model ecological island, waterfront development, natural wetlands, green corridors, urban gardens, living roofs, gardens on vacant spaces, green belt, wedges, and green nucleus.	N.S.	Practice
24	Santoro, S. *et al*. (2009) *Assessing stakeholders' risk perception to promote Nature Based Solutions as flood protection strategies: The case of the Glinščica river (Slovenia)*	Renaturing urban water bodies; Reduce canalization of the urban water bodies; Re-vegetation in urban areas; Re-establishing meandering and oxbows; Restore riparian vegetation; Construction of dry retention areas on flood plains; Create artificial water bodies for short term water storage; Use of balancing ponds to release water slowly; Forest management; Wetlands restoration; Stopping water transportation of trunks, branches and leaves; Preventing new erosion ditches in upper parts of river basin; Preventing bank erosion with short and forest vegetation; Removing cross wise barriers/dams; Renaturation of waterbodies; Rerouting floods to wetlands; Opening natural flood plains; Preventing new build up areas on flood plains; Removing buildings from flood plains where possible.	Flood.	Practice

25	Jagt, A. P. N. *et al*. (2017) *Cultivating nature-based solutions: The governance of communal urban gardens in the European Union*	Communal urban gardens.	Urban resilience.	Practice
26	Lafortezza, R., Sanesi, G. (2019) *Nature-based solutions: Settling the issue of sustainable urbanization*	Trees, canopy cover and biomass of city trees, and "room for the river".	Climate change and sustainability in urban areas.	Practice
27	Ruangpan, L. *et al*. (2020) *Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area*	Porous pavement, green roofs, rain gardens, vegetated swales, rainwater harvesting, dry detention pond, detention pond, bio-retention, infiltration trench, swale, and trees.	Hydro-meteorological risk reduction.	Theory and Practice
28	Short, C. *et al*. (2018) *Capturing the multiple benefits associated with nature-based solutions: Lessons from a natural flood management project in the Cotswolds, UK*	Large Woody Debris (LWD) dams, dry stone wall deflector, spring-fed and solar cattle drinking troughs, large earth bunds, small earth bunds/check dams, gully systems stuffed with wood, streamside fencing, large dry pond, trees planted, and many minor interventions such as diverting water away from tracks.	Flood.	Theory and Practice
29	Zhang, J. *et al*. (2019) *Quantitative evaluation and optimized utilization of water resources-water environment carrying capacity based on nature-based solutions*	N.A.	Water quality and availability.	Theory, Movement and Practice
30	Wild, T. C.; Henneberry, J.; Gill, L. (2017). *Comprehending the multiple 'values' of green infrastructure – Valuing nature-based solutions for urban water management from multiple perspectives*	Green spaces, greenways, green infrastructure, forest, space for water, parks.	Urban water management.	Practice

* N.S. – Not Specified

** N.A. – Not Applicable

SOURCE: the authors.

TABLE 3 – Examples of case studies with application of NbS.

Authors	NbS	Description	Objective	Case study	Procedures	Result	Co-benefits
Vujcic et al., 2017	Horticulture therapy	Intervention based on activities and experiences in a natural environment for the treatment of patients with stress and mental fatigue.	To improve mental health and well-being in urban areas.	Belgrade, Serbia	12 sessions (3 times a week for 4 weeks) of the standardized horticulture program, art therapy, and relaxation sessions with specific topics and objectives. All main activities involve working with live plants.	Depression, anxiety and stress reduction.	1. Increased group social support.
Short et al., 2018	Large Woody Debris - LWD	It consists of logs from trees or main branches of native plant species that are placed along the entire river channel with the objective of slowing down the water flow during flooding events, creating attenuation both in the channel and in the floodplain, and/or diverting high flows to preferred storage areas.	Flood mitigation.	Cotswold, England	1. In streams with continuous base flow, the base flow should continue unimpeded whenever possible. 2. Tree logs and branches should be left as long as possible and with the branches in place to reduce the possibility of movement. Ideally, length of the tree sections should be 1.5 to 2.5 times the channel width. 3. The tree logs should be secured with reinforced steel pins to create complex structures and ensure that the logs do not float during high-flow events. However, in some cases, wood can be left in place without pins.	Together with other actions (gully filling, earth dikes, grips and culverts), it managed to reduce the water levels of the rivers and the peak flow of floods.	1. Increased commitment and knowledge of the local population regarding the problem; 2. Reduction of damage to properties; 3. Improvement of the environmental and ecological conditions of the watershed (flow variability, channel functions and riparian habitats); 4. Reduction of the environmental impact associated with gray solutions.

Zölch et al., 2017	Green roofs and trees in pits.	A green roof is the roof of a building that is partially or completely covered with a layered vegetation system comprised by plants, root growth area, waterproof membrane, additional layers such as root barriers, and drainage and irrigation systems (Xing et al., 2017). Trees in pits are those planted in pits or openings within street medians.	Regulation of urban surface runoff.	Munich, Germany	Green roof on flat roofs. Trees planted 10 meters apart, only on one side of the street.	With a combination of green roofs and street tree planting (53% vegetation coverage), it is possible to reduce surface runoff by up to 14.8%.	Not mentioned.

SOURCE: the authors.

Among the authors who approach NbS as a set of practices, it was possible to identify principles, objectives and categories.

3.1.1. NbS objectives

Citing the European Commission, Lafortezza *et al*. (2018) present four main objectives in using NbS, namely:

1. To increase sustainable urbanization to stimulate economic growth and enhance the environment, making cities more attractive and improving human well-being.

2. To restore degraded ecosystems to increase their resilience, enabling them to provide vital services and withstand other social challenges.

3. To develop strategies for climate change adaptation and mitigation to provide more resilient responses and increase carbon storage; and

4. To improve management and offer synergies in reducing environmental risks and increasing resilience to generate more benefits than conventional methods.

3.1.2. NbS principles

NbS practices must follow some principles, namely:

1) NbS include nature conservation norms and principles;

2) NbS can be implemented either alone or in an integrated manner with other solutions to address social challenges (e.g., technological and engineering solutions);

3) NbS are determined by site-specific natural and cultural contexts, which include traditional, local and scientific knowledge;

4) NbS produce social benefits in a fair and equitable manner, in a way that promotes transparency and broad participation;

5) NbS maintain biological and cultural diversity and the ecosystems' ability to evolve over time;

6) NbS are applied on a landscape scale;

7) NbS recognize and address trade-offs between the production of some immediate economic benefits and future options for the production of ecosystem services; and

8) NbS are an integral part of the general arrangement of policies and measures or actions to face a specific challenge (IUCN, 2016, *apud* Cohen-Shacham *et al*., 2019).

3.1.3. NbS categories

Cohen-Shacham *et al*. (2019) mention that the approaches under the NbS umbrella term can be grouped into five categories:

a) Restorative (e.g., ecological restoration);

b) Problem-specific (e.g., ecosystem-based adaptation);

c) Infrastructure (e.g., green infrastructure);

d) Management (e.g., integrated water resources management); and

e) Protection (e.g., protected area management).

Citing Eggermont *et al*. (2015), Ruangpan *et al*. (2020) present three types of NbS:

a) NbS that address better use of protected or natural ecosystems, for example, protection of permanent preservation areas (with little or no human intervention);

b) NbS for sustainability and multifunctionality of managed ecosystems, for example, agroforestry (medium intervention); and

c) NbS for the design and management of new ecosystems, for example, green roofs or constructed lakes (high intervention).

3.2. Are NbS a scientific theory?

As a science, NbS are referred to as a theory (concept) or approach. Therefore, this is how we will treat NbS in this section. For example, Kabisch *et al*. (2016) refer to NbS as one of several concepts that promote maintenance, enhancement and restoration of biodiversity and ecosystems to simultaneously address multiple concerns. Citing Eggermont *et al*. (2015), Faivre *et al*. (2017) mention that NbS are a concept that is based on and supports other closely related concepts, such as the ecosystem approach. On the other hand, Panno *et al*. (2017) mention that the NbS approach offers sustainable solutions to deal with the climate change challenge in urban areas. These are some of the mentions of the expression NbS that place them in the category of scientific theory.

By scientific theory we refer to a set of proposals resulting from rational, objective, logical, systematic, verifiable and reliable thinking, as presented by Lakatos and Marconi (1992). These authors also present the components of science, as well as their classifications. Therefore, beyond how NbS are referred to, we will use the approach proposed by Lakatos and Marconi (1992) to assess NbS as a scientific theory. For the scientific classification, we will also use the works of Pombo, Levy and Guimarães (1994) and Funtowicz and Ravetz (1997), in addition to the aforementioned authors.

3.2.1 Scientific components of NbS

According to Lakatos and Marconi (1992), all science has three main components:

a) Objective or purpose;
b) Function; and
c) Object (material and formal).

Starting from the hypothesis that the NbS approach is a scientific theory, the question is: Which is its objective, function and object?

All the articles in our sample (Group C of articles) are part of the study of the NbS approach with a specific focus. From the objectives of the 100 articles in Group C (Annex F), it is possible to identify the purpose of the NbS approach as a scientific theory, which is generally to understand the relationships (flows and feedback) between the elements that make up social and ecological systems in proposing solutions that use nature to address socio-economic problems. For example, when dealing with climate change, the NbS approach seeks to identify the following, as presented by Lafortezza and Sanesi (2019):

1) The driving forces behind these changes (e.g.: urbanization process, soil sealing and increased use of private cars, among others);

2) The pressures exerted by these driving forces (e.g.: urban heat islands);

3) The changes suffered by the ecosystems due to these pressures (e.g.: impairment of regulatory services);

4) The impacts generated by changes in the ecosystems (e.g.: thermal discomfort);

5) The actions (NbS practices) that can mitigate these impacts by recovering the ecosystems' natural conditions of (e.g.: urban tree planting); and

6) Joint actions, public policies and governance (e.g.: incentive programs for the installation of green roofs) that can thus reduce the pressures and regulate the driving forces.

The aforementioned authors present these relationships through an analytical framework that seeks to understand the effects of NbS practices on the dynamics of urban areas concerning climate change. To develop this analytical framework, the authors relied on the DPSIR model (Driving Force-Pressure-State-Impact-Response).

The function of the NbS approach, in turn, is to enhance NbS practices through its growing body of knowledge about the relationships between the elements that make up social and ecological systems and the possible responses that applying NbS practices can generate in addressing socio-environmental challenges.

Finally, the material study object of the NbS approach, that is, what is intended to be studied, analyzed, interpreted or verified, in general, is the relationships (flows and feedback) between the elements that make up social and ecological systems related to the causes of socio-environmental problems and their solutions (for example, the processes/elements that lead to the formation of heat islands and the processes/elements that can lead to their reduction). Its formal study object, or its special focus, is NbS practices and the responses to these practices given by the elements of social and ecological systems in addressing various socio-economic problems (for example, the response provided by the implementation of green roofs to reduce temperature in urban areas).

Among the socio-economic problems mentioned by scientists in the NbS approach in our sample, we can mention the following: climate change, temperature rise and heat islands, water scarcity (in quantity and quality), coastal erosion, floods, species extinction, impacts of urbanization on natural areas, human health problems, unemployment, reduced human well-being, poverty, ecological gentrification, and hunger (see Table 2). The socio-environmental problems addressed by the authors of our sample are in line with the priority areas for NbS development, according to the IUCN and the European Commission, as cited by Albert *et al*. (2019).

3.2.2. Classification of the NbS approach as a scientific theory

According to Lakatos and Marconi (1992), sciences are classified into formal (study of ideas) and factual (study of facts). The NbS approach falls under the classification of factual sciences because it pertains to facts that are supposed to occur in the world and, as a result, it relies on observation and experimentation to verify (or refute) its hypotheses. Factual sciences are subdivided into natural and social sciences. As the NbS approach deals with the study of both social (e.g., human action) and natural

(e.g., ecosystems) elements, it is not limited to any of these classifications, nor to the classification of multidisciplinary science, as it transcends disciplinary barriers. Therefore, it can be classified as an interdisciplinary science, meaning that it combines diverse disciplines and knowledge to understand an object, although moving towards transdisciplinarity because there is a quest for:

a) Constructing a shared language;
b) Common foundations;
c) Identifying common structures and mechanisms for understanding reality; and
d) Formulating a unified and systematic view of knowledge (Pombo *et al*., 1994).

In this sense, Nesshover *et al*. (2017) mention NbS as an interdisciplinary perspective both as science, as well as a policy and practice. Song *et al*. (2019) emphasize the importance of interdisciplinary research in NbS development.

Adopting the classification proposal suggested by Funtowicz and Ravetz (1997), NbS can also be classified as a theory that falls within the field of problem-solving strategy of post-normal science[2]. According to these authors, "new problems related to risks and the environment have common aspects that distinguish them from traditional scientific problems: facts are uncertain, values are controversial, stakes are high, and decisions are urgent" (Funtowicz and Ravetz, 2017, p. 2019). They refer to the strategy for problem-solving suitable for this context as post-normal science.

The authors in our sample make clear mentions that frame the NbS theory as post-normal science. For example, when presenting the key elements for operationalizing the NbS concept, Nesshover *et al*. (2017) mention the following:

1) Dealing with uncertainty and complexity;
2) Ensuring the involvement of multiple stakeholders;
3) Ensuring good use of multi- and trans-disciplinary knowledge;
4) Developing a common understanding of cross-functional solutions, trade-offs, and natural adaptation;
5) Evaluating and monitoring mutual learning.

The participation of various stakeholders and different forms of knowledge is a prominent characteristic in the NbS approach, requiring the engagement of different stakeholders in problem identification, solution selection, implementation and monitoring, as verified in many of the articles in our sample that we cite below.

Among the seven lessons for planning nature-based solutions in cities, Frantzeskaki (2019) cites four that showed the striking characteristic of the NbS approach in terms of the participation of different actors:

1) NbS practices need to be aesthetically appealing to citizens so that they can appreciate and protect them;

[2] Funtowicz and Ravetz present three possible strategies for solving problems currently faced by humans, namely: applied science, professional consultancy, and post-normal science.

2) NbS create new common urban spaces, that is, public urban ecosystems that depend on the collective management and organization of different actors;

3) Different forums for the co-creation of NbS with social innovation are necessary; and

4) NbS require a collaborative governance approach.

In the proposal to implement NbS practices in the *European Horizon 2020* program, mentioned by Lafortezza and Sanesi (2019), the participation of different stakeholders is fundamental, during all stages. The NbS approach as a scientific theory is present in the evaluation and planning, design and monitoring stages. Therefore, knowledge production in these stages does not rely on pure science (traditional science) but on the application of post-normal science, using knowledge from different sources.

There are many mentions that evidence this characteristic of NbS regarding the participation of different actors. For example, Kabisch *et al*. (2016) propose indicators to measure citizen involvement as a prerequisite for the effectiveness of NbS. Citing the European Commission, Lafortezza *et al*. (2018) mention increasing citizen awareness, engagement and empowerment as one of the actions for renaturalizing cities. Citing the IUCN, Cohen-Shacham *et al*. (2019) mention as a principle of NbS that they include scientific, local and traditional knowledge. Nesshover *et al*. (2017) present the involvement of multiple stakeholders in the use of multi- and trans-disciplinary knowledge as a key element of NbS. Xing, Jones and Donnison (2017) mention citizen science as a tool for collecting and analyzing biodiversity data in areas where NbS have been applied. Albert *et al*. (2019) present the contribution of governance to NbS research, with one of the main contributions being providing an understanding of the current social system, its institutions and actors, identifying best NbS practices, and easing co-creation and co-implementation. Short *et al*. (2018) present the importance of local community participation and engagement in the management of the Stroud Frome river watershed in England to reduce flooding. In the NbS implementation guide presented by Raymond *et al*. (2017), the authors include frequent stakeholder engagement as the fifth stage. Song *et al*. (2019) assert that it is imperative to promote NbS by raising awareness among interdisciplinary stakeholders. Santoro *et al*. (2019) analyze the stakeholders' risk perception for promoting NbS as a flood protection strategy. In the application of an integrated NbS assessment model for water pollution control, Liquete *et al*. (2016) also work with the stakeholders' perceptions. Gulsrud *et al*. (2018) present the importance of community-based governance for the success of urban forestry strategies in Melbourne, Australia. Jagt *et al*. (2017) present the importance of social participation in the success of community urban gardens.

The involvement of different stakeholders in identifying socio-environmental problems, developing NbS practices and monitoring them for improvement can empower these actors to become protagonists in solving socio-environmental problems, in addition to providing these actors with practical and scientific knowledge that forces them to rethink and change their relationship with nature. This moment, mentioned in the literature as social learning (Pahl-Wostl, 2009), is present in several phases of the transformation of social and ecological

systems (Brasileiro-Assing *et al*., 2021). Therefore, the following question arises: Are Nature-based Solutions a transformation movement? We devote the next subsection to this question.

3.3. Are NbS a transformation movement?

By transformation movement we refer to actions aimed at transforming social and ecological systems. According to Moore *et al*. (2014), transformation describes a form of change that is more significant than adaptation, recombining the existing elements of a system in fundamentally new ways. In this sense, let us observe what some of the actors in our sample present to us.

Maes and Jacobs (2017) mention that NbS offer a reliable transition path of realistic incremental steps towards a new green economy. An economy with: reduced use of fossil fuels and increased renewable energy; reduction of trade-offs and increased synergy between systems; and increased job availability. In the same sense, Faivre *et al*. (2017) mention that NbS play an important role in promoting the transition from a resource-intensive growth model to a more resource-efficient, inclusive and sustainable growth model; and, citing Nevens *et al*. (2013), they add that transitions are radical innovations in structures, mindsets and practices that involve different sectors, domains and levels of a scale in the co-design and co-implementation of solutions. Albert *et al*. (2019) mention that the NbS approach can provide a new momentum to landscape planning by easing the implementation of a genuine ecosystem approach to watershed management. In other words, an approach that recognizes the ecosystems' structures and processes across all space and time dimensions, thus advancing current paradigms of integrated water resources management. Lafortezza and Sanesi (2019) mention that NbS are a unifying paradigm for advancing sustainable urbanization in Europe. Escobedo *et al*. (2019) also refer to NbS as a paradigm constructed from previous metaphors, a term they use to refer to approaches similar to NbS. By "paradigm" we understand "the achievements of science that, for some time, provide model problems and solutions for a community of practitioners of a science" (Kuhn, 1998, p. 13); or even "a set of recurring and almost standardized illustrations of different theories in their conceptual, instrumental and observational applications" (Kunh, 1998, p. 67). Colloquially, the term "paradigm" is mentioned as a model, prototype or rule (Lemos *et al*., 2019). Are we then in a transition process towards a new way of thinking and acting in the human-nature relationship? A new model of scientific achievements?

Based on the information presented in the previous sections, which analyze NbS both as a practice and as a science, there is no doubt that NbS actions and studies suggest changes in the way humans relate to nature through its use and management. In other words, NbS are a transformation movement. For example, a new form (a new model) of economic development that seeks harmony with nature; a new way of planning the landscape (urban and rural areas) so that humans and nature coexist in balance; a new form of governance, with participatory governance; a new way of conducting science, based on interdisciplinarity and post-normal science, etc. Therefore, the achievements, both practical and scientific, of NbS are part of a global environmental movement for the transformation of social and ecological systems.

Based on Moore *et al*. (2014), it is noticed that this transformation requires the following: identifying elements that can lead to the collapse of social and ecological systems (e.g., climate change); investigating alternative combinations of social and ecological elements (e.g., biofuels replacing fossil fuels, new legislation for the use of finite resources, etc.); a change in mentality; drivers/leaders of the transformation process (e.g., public, private and/or civil sector); experimentation with new alternatives; assessments of the results of these experiments; restructuring of initially proposed models; and, finally, expansion.

Figure 4 summarizes some of the main aspects (definitions, how they were mentioned, objectives and categories) of each NbS perspective (set of

Nature-based Solutions			
	SET OF PRACTICES	**SCIENTIFIC THEORY**	**TRANSFORMATION MOVEMENT**
DEFINITION	Actions, activities, operations and prctical work performes or proposed following certain procedures and using specific tools to achieve predefined objectives and goals.	A set of proposals arising from rational, objective, logical, systematic, verifiable and reliable thinking.	Actions aimed at transforming social and ecological systems.
MENTIONS	Action, solution, intervention or measure	Theory or approach	Transition path and promoter, progress of the current paradigms, pradigm
OBJECTIVES	Increase sustainable urbanization, restore degraded ecosystems, develop adaptation and mitigation strategies for climate changes and improve management and solutions to reduce environmental risks.	Understand the relationships (flows and feedback) between the elements that comprise the social and ecological systems in proposing solutions that resort to nature to face socioeconomic problems.	Offer a path for changes in the way in which humans relate to nature through its use and management.
CATEGORIES	1: a) Restorative; b) Problem-specIfic; c) Infrastructure; e d) Management; and e) Protection. 2: Requiring a) Minimum; b) Average; and c) High human intervention.	Factual and interdisciplinary science, which is framed within the problem-solving strategy field of post-normal science	Transformation
PROPOSED DEFINITION	**NbS are defined as practical actions, scientific theory and transformation movement aimed at studying, proposing and applying sustainable solution strategies for socio-environmental problems, based on understanding the functioning of balanced social and ecological systems and on re-signifying the relationship between humans and nature.**		

FIGURE 4 – Summary for proposing the concept of Nature-based Solutions. Columns 2, 3 and 4 present the definition, mentions, objectives and categories for each perspective of Nature-based Solutions – NbS (set of practices, scientific theory, and movement), based on the articles sampled. The last row presents the concept for NbS proposed by the authors of this article, which integrates the three NbS perspectives herein studied.
SOURCE: the authors.

practices, scientific theory, and movement), based on the study of the articles sampled, which served as the foundation for proposing a comprehensive definition for Nature-based Solutions that incorporates these three perspectives.

4. Conclusion

In this article, it was sought to understand what Nature-based Solutions (NbS) are based on their application and conceptualization in systematically selected and analyzed scientific articles. Based on the readings and discussions conducted, it was noticed that there is a need to analyze NbS from three different perspectives: a set of practices, a scientific theory, and a transformation movement. Although different, these perspectives proved to be complementary in understanding what NbS truly encompass.

While the use of the expression NbS was more frequent in the context of a set of practices, their principles, objectives and tools for development, application and monitoring make it clear that NbS are not only a set of practices but also a scientific approach, albeit a recent one under this nomenclature, and that they are part of a movement or represent a movement that seeks significant changes in the use and management of natural resources and in the way we address socio-environmental problems.

We identified shortcomings in each of these perspectives. As a practice, it was observed that the application of NbS is more focused on urban socio-environmental problems, which can be due to the fact that urban environments are more anthropized, generally of lower environmental quality and, therefore, more susceptible to NbS interventions. As a result, there were fewer studies focused on these practices in rural areas, which can be seen as a gap in the NbS approach as a scientific theory. Therefore, there is a need to increase scientific production and analyze NbS alternatives for addressing socio-environmental problems in rural areas. Additionally, studies are still largely focused on researching solutions for climate-related problems, even though NbS have the potential to address many other socio-environmental issues, which, while related to climate change, deserve special attention, such as biodiversity loss, hunger, water scarcity and human health.

As a movement, it is necessary to recognize NbS as such and tone them up for their expansion. The engagement and participation of multiple stakeholders stand out among the necessary actions, given their importance for strengthening NbS as a movement. Additionally, not the majority but a few authors perceived the expectation that NbS should generate economic growth, an outdated conception that has been replaced by the notion of development. Therefore, it is necessary to homogenize the discourse; otherwise, the transformation process may fall into an adaptation one.

In conclusion, as a concept that integrates these three perspectives, we define NbS as practical actions, a scientific theory and a transformation movement aimed at studying, proposing and applying sustainable solution strategies for socio-environmental problems, based on understanding the functioning of balanced social and ecological systems and re-signifying the relationship between humans and nature.

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