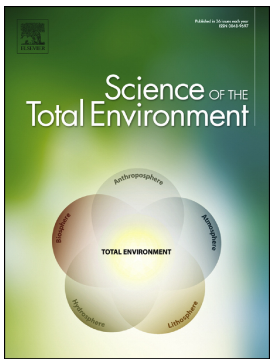

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The knowledge transfer potential of online data pools on Nature-based Solutions

Barbara Schröter[1*], Aude Zingraff-Hamed[2], Edward Ott[1], Joshua Huang[2], Frank Hüesker[3], Claire Nicolas[1], Nadine Jenny Shirin Schröder[4]

*Corresponding author

[1] Leibniz-Centre for Agricultural Landscape Research, Working Group "Governance of Ecosystem Services", Eberswalder Str. 84, 15374 Müncheberg, Germany.
barbara.schroeter@zalf.de; ORCID 0000-0001-8066-3146
Edward.Ott@zalf.de;
Claire.Nicolas@zalf.de

[2] Technical University of Munich, Chair for Strategic Landscape Planning and Management, Emil-Ramann-Str. 6, 85354 Freising, Germany
aude.zingraff-hamed@tum.de; ORCID: 0000-0001-7602-7830
josh.huang@tum.de; ORCID 0000-0003-0293-8523

[3] Helmholtz Centre for Environmental Research, Permoserstr. 15, 04318 Leipzig, Germany
frank.hueesker@ufz.de
ORCID: 0000-0002-1412-8588

[4] Leuphana University Lüneburg, Research Group Governance, Participation and Sustainability, Lüneburg, Germany
nadine.schroeder@stud.leuphana.de; ORCID 0000-0003-1636-9497

Abstract

Improving the adoption of Nature-based Solutions (NBS) requires learning from successes and failures. Knowledge derived from implemented cases helps to identify for instance drivers and barriers of NBS implementation, generates lessons learned, and supports their upscaling. Online data pools that catalogue information from NBS case studies may help scientists and practitioners to create this knowledge. The aim of this review is to assess the knowledge transfer potential of online data pools for implementing and upscaling NBS. For that, we compared 21 online data pools that report on NBS case studies in terms of topics, availability and quality of information on NBS. We found a high variability in quantity, type and quality of the information documented, hindering comparability and limiting knowledge transfer. Our results show that the most common knowledge provided was on actions undertaken on NBS, their outcomes, case study site descriptions, specific challenges and information on responsible entities and partners. Information on key attributes of NBS, such as on ecosystem processes and services as well as on governance and financing issues, was often omitted. The missing information however would be important for further comparative research to overcome implementation gaps for NBS. Based on the discussion of our findings we propose categories for a more efficient online data pool and give recommendations for further research on NBS.

Keywords

Implementation barriers, Upscaling, Governance, Financing, Ecosystem Services, Amplification

1. Introduction

Nature-based solutions (NBS) to address climate change impacts and to support the achievement of the United Nations Sustainable Development Goals (SDGs) rank high on the political and research agenda in Europe for the time being (Faivre et al. 2017). NBS are a relatively new concept emerging from policy, which is increasingly being taken up by science. The most prominent definitions are from the IUCN and the EU. The IUCN (Cohen-Shacham et al. 2016) focuses more on nature conservation, defining NBS as "actions to protect, sustainably manage and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits." The European Commission (EC) centres its definition on social and economic goals defining NBS as "actions which are inspired by, supported by or copied from nature. […] Many nature-based solutions result in co-benefits for health, the economy, society and the environment, and thus they can represent more efficient and cost-effective solutions than more traditional approaches" (European Commission 2015). We follow upon our previous work and understand NBS as actions that: (i) alleviate a well-defined societal challenge, (ii) utilize ecosystem processes of spatial, blue and green infrastructure networks[1], and (iii) are embedded within viable governance or business models for implementation (Albert et al. 2019).

Ultimately a lot of scientific literature has been produced on NBS, with most of them stating knowledge gaps and implementation hurdles for NBS. For instance, Frantzeskaki et al. (2020) stated that practitioners need system thinking and solution-oriented thinking as a knowledge base and that partnerships and collaborative

[1] "*Blue-Green Infrastructure (BGI) is an interconnected network of natural and designed landscape components, including water bodies and green and open spaces*."(Ghofrani et al. 2017)

governance models are crucial for implementing NBS. Similarly, Enzi et al (2017:177) identified three barriers for NBS implementation: 1) technical knowledge gaps; 2) missing internal collaboration links between different municipality departments (e.g., urban greening and water); and 3) absence of strong communication strategies towards citizens. Ershad Sarabi et al. (2019) are even more detailed when listing enablers and barriers of NBS implementation and identified the following NBS enablers: partnerships, effective monitoring, knowledge sharing, financial instruments, supporting legislation, education and training, combining with grey infrastructures, open innovation and experimentation and appropriate planning and design. Identified barriers are uncertainty regarding the implementation process and the benefits arising from NBS, followed by inadequate financial resources, land and time availability, path dependency in decision making, institutional fragmentation, and inadequate regulations. In summary, to advance NBS implementation further, knowledge on the involved systems and their components (Fernandes and Guiomar 2018) is needed, mostly on cost-benefit and financial aspects (Sahani et al. 2019, Hobbie and Grimm 2020) and on collaboration and governance (Kabisch et al. 2016, Calliari et al. 2019).

For gaining this knowledge learning from other experiences in NBS implementation is essential. That is why one of the main objectives of the European Commission´s Horizon 2020 Program is to “provide the evidence and a knowledge base for NbS and advance the development, implementation and scaling up of innovative NbS.” (Cohen-Shacham et al. 2019). It is introducing co-design, demonstrator cases and social science studies from which other cases should learn (Faivre et al. 2017).

Online data pools, which host these case studies are important for providing this knowledge and enabling comparisons of different NBS implementation cases.

Ultimately, there has been an increasing effort in building online data pools on NBS. Yet, it is unclear if these pools really deliver the required knowledge for implementing and upscaling NBS. To fill this gap, the objective of this contribution is to provide an overview of the knowledge transfer potential about NBS in online data pools. We particularly aim to analyse and discuss the information provided in NBS online data pools in order to formulate recommendations for future elaboration of online data pools.

Particularly, we address the following research questions:

1) How is information on NBS in data pools organized and presented?
2) How accessible is the data for users?
3) What kind of information is contained or missing in NBS data pools?
4) What is the quality of the information presented?

Based on our findings, we provide recommendations on how the structure of the data pools can be improved to leverage the experience and findings of previous case studies for upscaling and learning.

To answer these questions we analysed 21 online data pools that provide information on NBS case studies. In the remainder of the paper, we describe the selection of these data pools and explain the methodology for content comparison and quality assessment. Based on the discussion of our findings we propose an ideal online data pool and give recommendations for further research. Then we end with some concluding remarks.

2. Method

The methodological approach of the paper (figure 1) relies on a three step linear analysis. First, data pools recording NBS cases were collected and selected. Second,

a systematic analysis of the content was performed to assess the quantity and quality of the data as well as the content informed. Finally, we discussed the results in order to formulate recommendations for the improvement of NBS online data pools.

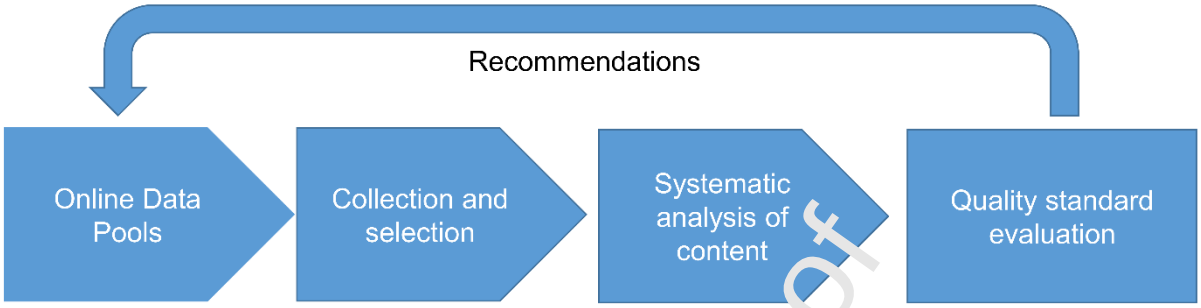

Figure 1. Methodological approach

2.1 Collection and selection of online data pools

Researchers and practitioners benefit from the visibility of online open source data and the potential learning effects that the data promote. To collect NBS data pools that are most likely to contribute to learning and cross-fertilization processes we conducted a systematic online search, applied a snowballing approach to the results recorded from the online search and included additional data pools resulting from ongoing research within our network. For this first listing of NBS data pools, we did not apply any restrictions regarding the NBS' objectives or settings. The collection of the dataset was performed in June 2019. First, we ran a query through the Google search engine using the search term "nature-based solutions database". We decided to record search results from Google only, since with over 75 percent of the search market share, it is the most used search engine worldwide (Davies 2018). We used the Google search engine because we were not looking primarily for scientific publications on the topic (unlike Debele et al.) but for data pools that are located at the science-public-policy interface and that provide information on the topic for practitioners or the general public. Using this fixed and strict search string may have

prevented finding all relevant data bases at the moment of searching, but we think that due to the fact that we were using a web search engine and not a scientific database, this can be neglected. The strict search term also was used to narrow our field of analysis, even when we omitted data pools with similar aims but using different terms other than NBS.

We screened the first 100 results and collected the websites which clearly contained data pools on NBS. Then we added further online data pools using a snowball approach by adding websites that were cited as sources for data pools within the initial collection of data pools from the online search. For example, the Oppla data pool gathers data from different sources, such as the ThinkNature website. Finally, we added data pools of ongoing research from our institutes or our scientific networks. This resulted in the collection of a set of 59 data pools with information on NBS.

In a second step, the data pools were refined for further analysis according to a number of selection criteria. The first selection criteria was the language used. We excluded all data pools that were not at least translated into English. Second we excluded data pools that do not list clear NBS measures but rather focus on similar but different concepts, such as climate change adaptation or river restoration. After applying these criteria, 21 online data pools containing information on NBS case studies remained.

2.2 Data analysis

We conducted a comparative content analysis for all data pools (Stow et al. 2006). In each data pool we assessed the webpages with NBS examples from practice and captured the information categories provided for each NBS example. For instance, on the FramWat website the information provided on each NBS case are catchment name and country, justification, activities, characteristics, tool, analysis and maps. We then grouped the information categories into broader categories to quantify which information on NBS is provided by the data pools and to compare the information between the different pools.

We further performed a data pool quality assessment. For each data pool providing information on implemented or ongoing NBS cases, we screened ten randomly chosen cases to estimate the data availability and quality. For a data pool with less than ten cases, we screened all case entries. For each data pool, we assessed all available variables in the data pool for the quality of the information provided on each variable in a given data pool. To quantify the quality of each category we developed a trichotomous numerical rating scheme that we applied to each category in the 21 data pools (Jacoby and Matell 1971). To avoid quality assessment biases due to inherent traits of likert-scale such extreme response, we used a 3-point scale (Tsekouras 2015). After assigning quality ratings from 1 “poor quality”, 2 “medium quality” to 3 “good quality” to each category of 10 randomly selected cases per data pool (Singh 2003). Some data pools had less than 10 cases, and the mean was taken with the respective $n < 10$. We calculated the mean quality rating per category. We repeated that process for all 21 data pools. We then used the mean quality ratings of the categories to calculate an overall quality rating for the data pool (see example in Table 1).

Table 1: Quality standard evaluation of the data pools

Qualitative value of the information	Numerical marks	Description	Example for the category “project cost”
no data (despite availability of the variable)	0	NA, “-“, no entry, irrelevant comments or similar entries	NA
poor quality	1	information is provided as a category or as a multiple choice list	<1.000.000 €
medium quality	2	The information provided is in a fairly precise form, e.g. free text entries	around 1.000.000 €
good quality	3	The information provided is in a precise form	1.000.250 €

The quality of the cases was estimated on the data available online between the 1st and the 15th of February 2020. The first five cases were estimated twice, as the first and the last cases assessed, to avoid change in the assessment procedure due to expectation change.

3. Results

3.1 Organization and presentation of data

An overview of analysed data pools is presented in table 2.

Table 2: Online published data pools were studied in this contribution

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
1	Oppla	https://oppla.eu/case-study-finder	Database	Repository of NBS for a broad range of people from science, policy and practice. "It provides a knowledge marketplace where the latest thinking on natural capital, ecosystem services and nature-based solutions is brought together." It is funded by the European Commission FP7 Programme as a joint activity between the OPERAs and OpenNESS projects.	Worldwide
2	Nature Based Solutions Initiative	https://www.naturebasedsolutionsinitiative.org/NBS-case-studies/	Webpage catalogue	An interdisciplinary programme of research, policy advice and education based at the University of Oxford providing gathered knowledge on NBS through an evidence platform and policy platform.	Vanuatu, Burkina Faso, Nepal, India, Netherlands, Bangladesh, USA, Kenya, Peru, Belarus, Ethiopia, UK, Sierra Leone,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
					Kenya
3a	Naturally Resilient Communities *	http://nrcsolutions.org/strategies/#solutions	Database	Guide of nature-based solutions and case studies of successful projects from the US, providing knowledge for communities. Partnership of various US associations.	USA
3b	Naturally Resilient Communities *	http://nrcsolutions.org/strategies/#solutions	Database		USA
4	FramWat	https://www.interreg-central.eu/Content.Node/FramWat.ht	Webpage catalogue	Website of an Interreg Central Europe Project to strengthen the regional common framework for floods, droughts and pollution mitigation by increasing the buffer capacity of the landscape.	Slovakia, Slovenia, Poland, Hungary, Croatia, Austria

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
		ml			
5	Nature insurance value	http://naiad2020.eu/demo-cases/	Webpage catalogue	European Union's Horizon 2020 project on the assessment and demonstration of Nature Insurance Value.	Denmark, Poland, Netherlands, Spain, France (2), Romania, UK, Slovenia
6	Think Nature	https://platform.think-nature.eu/case-studies	Database	A multi-stakeholder communication platform supporting the understanding and promotion of NBS funded by European Union's Horizon 2020 project.	Worldwide
7	Naturvation	https://naturvation.eu/atlas	Database	European Union's Horizon 2020 project on the assessment of NBS in cities for responding to urban sustainability challenges by working with communities and stakeholders.	Belgium (20), Bulgaria (20), Croatia (10), Czech Republic (10), Denmark (10), Estonia (7), Finland (10), France (96), Germany (150), Greece (12),

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
					Hungary (22), Ireland (10), Italy (91), Netherlands (30), Norway (20), Poland (69), Portugal (31), Romania (38), Slovakia (10), Slovenia (10), Spain (91), Sweden (31), Switzerland (10), United Kingdom (192)
8	Equator Initiative	https://www.equatorinitiative.org/knowledge-center/nature-	Database	The Equator Initiative is a partnership of the United Nations, governments, civil society, businesses and grassroots organisations to provide opportunities for indigenous and local communities around the world	Worldwide

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
		based-solutions-database/		to address the challenges of land degradation, biodiversity conservation and livelihood improvement in a socially equitable manner.	
9	RECO-NECT	http://www.reconect.eu/network-of-cases	Webpage catalogue	European Union's Horizon 2020 project on demonstrating, referencing, upscaling and exploiting large-scale NBS for hydro-meteorological risk reduction in rural and natural areas.	Demonstrators: Germany, Denmark, Spain, Italy; Netherlands, Austria, Denmark, Switzerland, France (2),; Collaborator cases: Bulgaria, Poland, Croatia, Serbia (2), Thailand, Taiwan (2), Brazil, Malaysia, China, Myanmar,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
					Australia, USA (2), Peru, Colombia (2), Caribbean/St. Marten
10	ReNature	http://renature-project.eu/compendium	Database	Open-source compendium for all kind of stakeholders with data on NBS in Malta. Funded as a European Union's Horizon 2020 project.	Malta
11	Grow Green Project	http://growgreenproject.eu/city-actions/frontrunnercities/	Webpage catalogue	European Union's Horizon 2020 project on creating climate and water resilient, healthy and liveable cities by investing in NBS.	UK, Spain, Poland, China, Italy, France, Croatia
12	UNALAB	https://unalab.eu/our-cities	Webpage catalogue	European Union's Horizon 2020 project on the development of smarter, more inclusive, more resilient and	Finland, Netherlands, Italy; Turkey, France, Spain,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
				more sustainable cities through the implementation of nature-based solutions.	Czech Republic, Norway, Argentina, Hong Kong
13	Nature-based solutions/Natural hazards	https://naturebasedsolutions.org/map/	Database	The platform is a hub for projects, investments, guidance and studies making use of nature to reduce the risks associated with natural hazards. It is a partnership of the World Bank Group and Deltares.	Worldwide
14a	Nature4Cities*	https://geocluster4NBS.nature4cities-platform.eu/#/pioneers	Database	Platform that provides knowledge repositories, tools for the assessment of benefits, co-benefits and costs of NBS projects and for stakeholder's participation processes for municipalities, experts and citizens. Funded as a European Union's Horizon 2020 project.	Switzerland, UK, Netherlands, Italy, France, Hungary, Germany, Austria, Spain, Turkey
14b	Nature4Cities*	https://geocluster4NBS	Factsheet (PDF)		Switzerland, UK, Netherlands, Italy, France,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
		.nature 4cities-platform .eu/#/pioneers			Hungary, Germany, Austria, Spain, Turkey
15	Phusicos	https://phusicos.eu/case-studies/	Webpage catalogue (with link to poster)	European Union's Horizon 2020 project on effectiveness of NBS to reduce the risk of extreme weather events in rural mountain landscapes.	Norway, Germany, Austria, Italy, Spain/France/Andorra (Pyrenees case study)
16	Operandum	https://www.operandum-project.eu/	Webpage catalogue	European Union's Horizon 2020 project on tools and methods for the demonstration and **market uptake of Nature-Based Solutions to reduce hydro-meteorological risks.**	Australia, Austria, China, China (Hong Kong), Finland, Germany, Greece, Ireland, Italy, UK
17	proGIreg	https://progireg.eu/	Webpage catalogue	European Union's Horizon 2020 project on the use of productive Green Infrastructure for post-industrial urban regeneration	Germany, China, Italy, Croatia, Portugal, Romania,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
				with and for citizens.	Greece, Bosnia and Herzegovina
18	ConnectingNature	https://connectingnature.eu/cities	Webpage catalogue	European Union's Horizon 2020 project on the impact of NBS initiatives on climate change adaptation, health and well-being, social cohesion and sustainable economic development in cities. The focus is on innovative actions of commercial and social enterprises.	UK, Belgium, Poland, Spain, Italy, Bulgaria, Greece (2), Spain, Cyprus, Bosnia and Herzegovina
19	Urbinat	https://urbinat.eu/cities/	Webpage catalogue	European Union's Horizon 2020 project on the regeneration and integration of deprived social housing urban developments through an innovative and inclusive catalogue of NBS.	France, Portugal, Bulgaria, Belgium, Denmark, Slovenia, Italy, Iran, China
20	Clever Cities	https://clevercities.eu/	Webpage catalogue	European Union's Horizon 2020 project on the potential of NBS for improving the	Germany, UK, Italy, Serbia, Greece, Spain,

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
				environment, creating economic opportunities and fostering health by making cities greener.	Sweden, Ecuador, Romania
21	Uban Green Up	https://www.urbangreenup.eu/cities/	Webpage catalogue	European Union's Horizon 2020 project on the development, application and replication of Renaturing Urban Plans in cities with the aim to mitigate the effects of climate change, improve air quality and water management and implementing NBS.	Front-runners: Turkey, UK, Spain; Followers: China, Germany, Italy, Colombia, Vietnam; Network of cities: Denmark, Cyprus, Italy, Portugal, Portugal, Hungary, Greece, Greece, Czech Republic, Ukraine, Spain, Norway, Portugal, Cap

No.	Name	Link	Type of data pool	Description	Geographical scope - Case study countries[1]
					Verde, Spain, Finland, Sweden, Brazil

* On the *Naturally Resilient Communities* website, one can filter the data pool according to case studies or solutions. On the *Nature4cities* website, there is different information on the case study depending on if one views the website or the factsheet. This is why both websites were entered twice into the analysis

[1] The figures in parenthesis indicate the number of case studies in each countries, if available

We identified two types of data pools: online databases and webpage catalogues. In databases, the data variables of NBS case studies are organised though different predefined categories, e.g. community type, scale, cost, NBS type etc. Generally, online databases offer greater functionality to the user than webpage catalogues. They contain sophisticated search and filter functions, which allow the user to search for specific NBS cases or to filter for specific case characteristics according to the database categories (e.g. all NBS implemented in urban areas). Especially the usability and functionality of the filter function in databases is important as it offers users structured access to selected information. In other words it unlocks custom information that is relevant for the user specific requirements and allows for the selection of comparable information.

Webpage catalogues are part of a website and provide more informal, less structured but often more detailed descriptions of NBS cases. For example, within the website of a research project the case study sites are presented (e.g. on the Phusicos website). In webpage catalogues, the quality and quantity of information for each case study can strongly differ, since there are no predefined categories that allow a structured collection and representation of the data, e.g. Urbinat and Clever Cities. Furthermore, the description of the cases sometime does not rely upon certain categories, e.g. in the Grow Green's and the Phusicos' web page catalogues.

Web page catalogues do not offer the wide range of functionality that online databases offer to the user. Their potential to provide searchable, comparable and user specific data is therefore limited. A good example for additional functionality provided by a webpage catalogue is the Nature Based Solutions Initiative website that offers the user the option to filter information in two ways: by solutions or by case studies.

3.2 Accessibility of data

The dataset is composed of eight databases and 13 webpage catalogues (Table 1.). In most of the data pools, the content can only be browsed online. A download of the data, for example as a cvg-file, which would allow further data processing was not possible. Only a minority of the data pools allow the users to download files, e.g., PDF-files, to access case descriptions (Naturally Resilient Communities, Natural Hazards) or a poster (Naiad, Reconect, Phusicos). Nature4Cities integrated comprehensive fact sheets to provide detailed case information. The database allows for the selection of NBS cases along the overarching categories of “objects, shapes and physical projects” and “strategies and actions.” The information displayed within the database’s web interface is aggregated and only allows a broad overview of the case. In addition to the aggregated information, the database offers the user the possibility to download a detailed fact sheet of the case, containing further standardized information that is not displayed in the web interface of the database.

Also the manner in which the information is presented in databases and webpage catalogues differs. Mainly, the databases depict the information in boxes using short keywords (e.g. Nature4Cities, NaturebasedSolution.org), while the webpage catalogues mainly present the information as detailed written text (e.g. Connecting Nature; Phusicos, Unalab, GrowGreen Project).

3.3 Information provided in data pools

When analysing the content of the online databases we noted that the presentation of the stored data is mostly consistent within the databases. However, not all categories contained variables. Sometimes, if no information was entered for a

particular category, the respective category was not displayed on the case-specific webpage.

Across these data pools a wide diversity of terms is used to record the NBS case studies, generally on a separate webpage. They are referred to as case study (n=6), solution (n=4), city (n=7) or other terms like pilot areas, pioneer project, demonstrators or Open Air Labs (OALS) (n=3) (see table 3). When opening a case specific webpage, the NBS case studies are labelled with a title, which can be the name of the city (e.g. “Manchester” on GrowGreen), the name of the solution or measure (e.g. “Rain Gardens” on Naturally Resilient Communities), the type of solution and the location (e.g. „Restoration of a recreation area in Kräppladalen, Stockholm, Sweden” on Naturvation), the city name and the country (e.g. “The city of Copenhague, Denmark” on NAIAD), the project name (e.g. “Restoring Coral Reefs in the Face of Climate Change in the Seychelles” on Natural Hazards/Nature-based Solutions), the catchment name and the country (e.g. “Tordera River Basin, Catalonia” on Reconect), or the name of the city and the success (UrbanGreenUp).

The data pools´ contents are diverse. However some similarities exist (see table 3, also for all “n”). The majority of data pools provided a case study description, referred to as description (of demonstrator and case study) (n=18), information about the city (n=8), regional considerations (n=3), community type (n=2) and/or a description of the actions undertaken in the case study sites, which in most cases are referred to as nature-based solutions (n=14), but also as interventions (n=6), labs (n=2), implementation (n=2), tools (n=2) or monitoring (n=1). In more than half of the cases (n=13), the exact location of these actions is stated, often accompanied by a map. Rarely, did the data pools have categories such as “news” updated, e.g. “Latest News from Dortmund” on ProGIreg. In some cases, the overall context for the case

study is depicted, as well as the scale of the case study and the goals of the project. Challenges that are addressed by the solutions and the expected outcomes/impacts are also explained. When data pools contain information about governance issues, then it is in terms of stakeholders involved, the financing of the projects, the timeframe and the responsible project partners. Often, there are links to related websites and hints about helpful sources. Most of the websites use photographs of the case study sites. Additionally, some use icons to make the information more attractive, e.g. for the type of solution (UrbanGreenUp), key challenges, urban setting and project cost (Naturvation), or the SDGs (Equator Initiative).

Table 3: Information presented in NBS Databases by variables (for additional information on grouping the exact wording in the data pools see annex)

Overall category	Category	Number of data pools containing category
Term to list NBS cases	Case study	6
	City	4
	Solution	7
	Other	3
NBS case study title	Name of Solution/Measure	4
	Type of solution + location	4
	Catchment name and country	2
	City and Country	3
	Name of the city	5

	Project Name	3
	Country	1
	Name of city and success	1
Challenges	Hazards addressed	5
	Challenges	3
Location	Location	5
	Map	8
Case study description	Description (of demonstrator and case study)	18
	Related case studies	2
	About the City	8
	Community Type	2
	Regional considerations	3
Context	Context	1
	Key figures	1
	Keywords	2
	Ecosystems	2
Actions	Nature-based Solutions	14
	Labs	2
	Interventions	6
	Implementation	2
	Monitoring	1

	Tool	2
Scale	Scale	5
Goals	Goals	5
Project responsible entities	Executing Entity	1
	Project partners	5
	Contact	5
Governance	Stakeholder/aspect	5
	Governance	1
	Legal aspects	1
Financing	Costs	4
	Funding/Financing	6
Timeframe	Project duration	3
Outcomes/Impacts	Outcomes/Impacts	7
	Benefits	8
	Co-benefits	1
	SDGs	5
	Replicability	3
	Lessons learned	2
	Publications and reports	1
Links	Links	9
News	News and events	3
Sources	Source/References	4

	Additional Resources	1
Other	Additional comments (optional)	1
	Videos and stories	1
	Awards	1
	Analysis	1
	Other	2

When looking at the geographical location of the case studies (Table 1), for the web catalogues, most of them are in Europe, with some including single cases in Asia, Latin America or Africa. Two databases only focus on a single country: Naturally Resilient Communities (USA) and ReNature (Malta). Four databases list case studies from all around the world (Oppla, ThinkNature, EcuatorInitiative, Nature-based solutions/Natural hazards). Interestingly, in these databases case studies from Russia, Canada and Australia are completely missing or scarce (EcuatorInitiative).

3.4 Data quality

The data pools' mean data quality is estimated at 1.8 (2 representing medium quality). The best data pools are Nature4Cities (2.7), ReNature (2.6), the Nature based Solution Initiative (2.5), Phusicos (2.5), Connecting Nature (2.5), Operandum (2.2) and Nature insurance value (2.1) (Figure 2 and Table A1).[2] Except for the Nature based Solution Initiative, they are all the result of EU funded research projects. Interestingly while Oppla is one of the larger databases available and

[2] The Grow Green Project scored the highest mean quality value among all data pools. That result however, is based on only one category, a detailed case description. The Grow Green Project, therefore does not qualify for comparison with the other data pools and was excluded as an outlier.

receiving funding renewal from the EU, the quality of the information provided is the poorest.

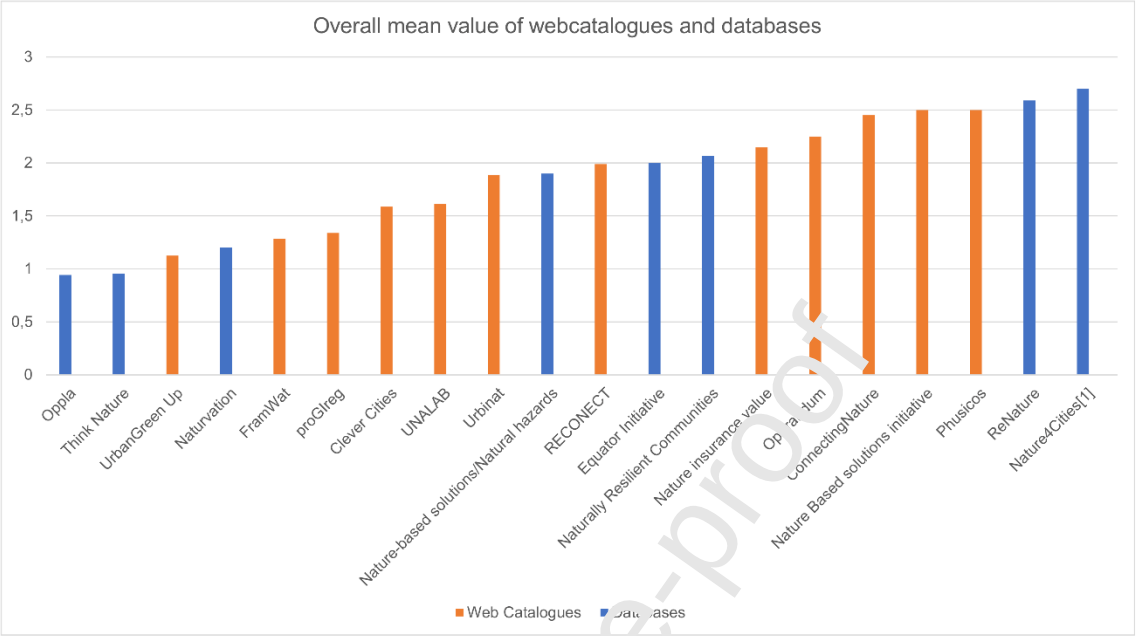

Figure 2: Quality of the screened data pool according to mean values; databases in orange, webpage catalogues in blue.

Observation of the value per variable (Figure 3) indicated that data pools with a good quality rating of the information they provide contain fewer variables and consistently show high quality per variable. Data pools with the poorest quality contain many variables but only a few of the fields are filled in. Consequently, the overall data quality is low but the quality for a single variable could be high. Webpage catalogues provide higher quality information but the data is not as accessible and requires more time to read as the data is not presented in a consolidated manner but as a detailed and long text description. Databases are generally of lower quality but contain many variables with a high diversity of quality and provide easier access to the data, which makes the data compilation for case comparisons and further data analyses easier and less time consuming.

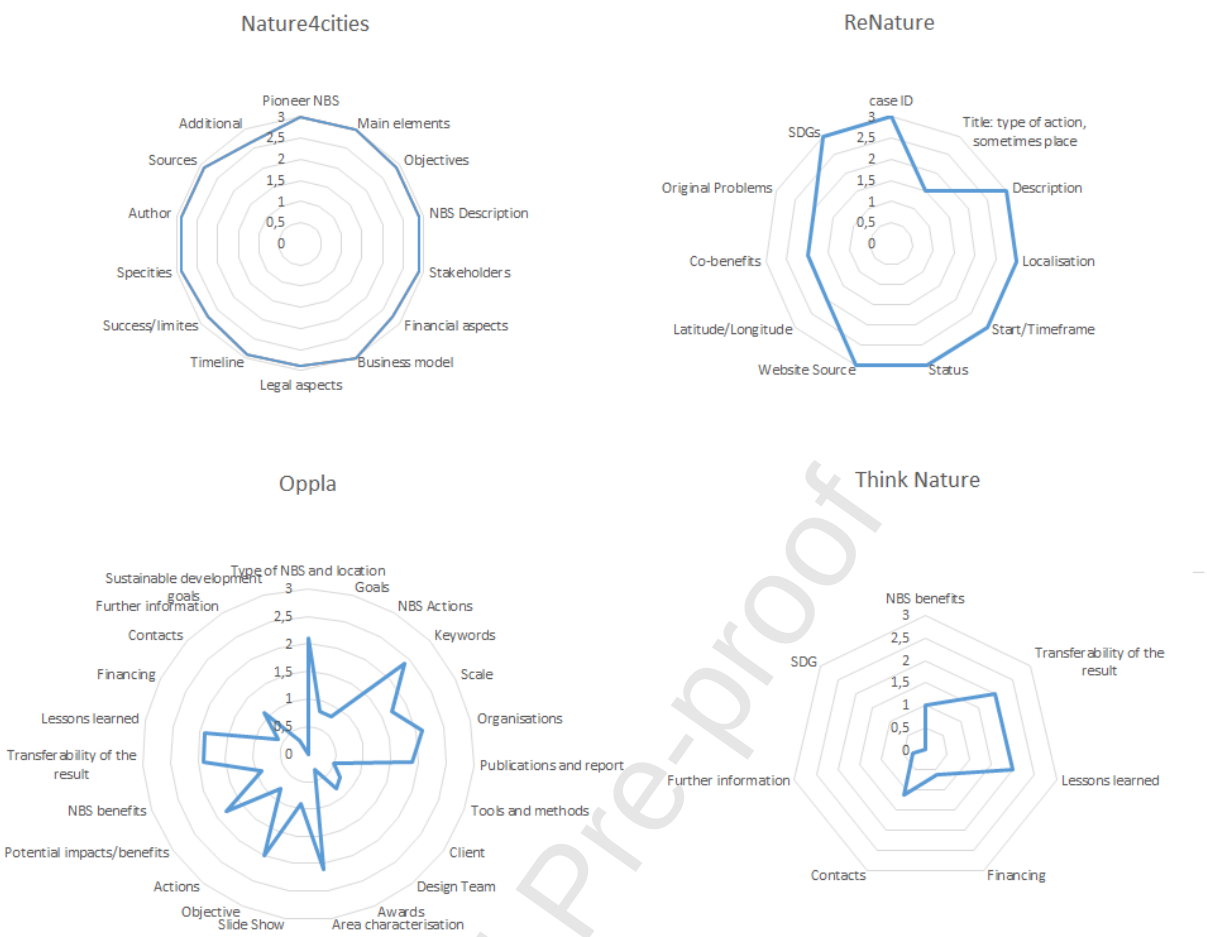

Figure 3. Value of each variable of the two data pools with highest quality (Nature4Cities and ReNature) and the two data pools with the poorest quality (Oppla and Think Nature).

4. Discussion

NBS design and implementation rely on applied science, signifying that learning from other's successes and failures is a crucial step for the evolution of robustness, efficiency and scale of implementation. In this context, we analysed the content of 21 online data pools on NBS to provide an overview of the state of their knowledge transfer potential and to formulate recommendations for future elaboration of online NBS data pools.

4.1 Online data pool quality

We found a high variability in quantity, type and quality of the information documented, which hinders comparability and limits knowledge transfer. The detected differences of the data pools are, in part, due to the data pool type. Individual projects like RECONECT or UNALAB that present their respective case studies on the project website as webpage catalogues tend to be more creative and qualitative in their information compared to cross-cutting databases which represent different projects (e.g. Oppla, Think Nature Platform). If the data pools are databases, they enable a quick overview of the case studies and their selection but describe them only superficially. Databases that synthetize data pools such as Oppla have a greater number of variables but the poorest quality as information gets lost every time that the case description is transferred to another database.

Also, in databases the entries are often diverse since not all categories are always displayed. As a result, the user may not know if this information exists, and it becomes hard to compare the case to other cases where all information is available. On the contrary, for project websites the quality of the entries notably differs, as there may be no strict requirements on the content, or websites' content curators do not sufficiently check the quality of records.

The results of the study underscore the lack of complete information regarding NBS in online data pools. This is in line with conclusions from Debele et al. (2019) who examined databases on NBS for natural disasters and hazards, and Mackenzie Smith (2019) who analysed the content of websites on NBS for disaster risk reduction and climate change adaptation. Debele et al. (2019) state that only limited research is available on economic costs and benefits, and that this information would be fundamental knowledge for the uptaking of NBS. "Other research needs to include

the development of NBS catalogues that contain harmonised and comprehensive databases and metadata models for NBS. A significant gap exists among the science, policy and practice of NBS needs, warranting future investigations to explore and build a bridge that can enhance the market opportunities of NBS over purely grey approaches" (Debele et al. 2019: 18). Mackenzie Smith (2019) emphasizes that there is no equal information for the different policy levels – the European, the national, the regional and local level – available: "very rarely were policies at all three levels mentioned, and the combination of European and national level policies was the most common combination of any two policy levels [...] some policies that seem like ideal instruments for implementing NBS were not mentioned in any of the case studies analysed" (Mackenzie Smith 2019: 33-34).

The COST Action CA17133 Circular City (https:// circular-city.eu/) 'provides a network for researches and practitioners from different fields to investigate the use of NBS for circular flow systems in cities. One of the network´s objective is to "identify and address regulatory, governance, financial and legal drivers and barriers for NBS implementation and use of recovered resources, and support institutional change to better regulatory governance" (Langergraber et al. 2020). This shows that science is already working on these topics, however results have to be well documented and accessible to the public.

Most case studies registered in the data pools are situated in Europe. This may be due to the fact that many data pools are part of Horizon 2020 projects. The European Commission launched a special program for NBS in cities and is fostering the concept in general. Also, the concept of NBS so far is mainly pushed by the EU and the IUCN while other regions refer to NBS measures sometimes with different terms, like "water sensitive urban design" (WSUD) in the case of Australia amongst others

(see Fletcher et al. 2015). To fill this knowledge gap future research projects may therefore focus on documenting NBS case studies in Asia, Africa and Latin America, as well as Canada, Russia and Australia, where so far almost no information is available (cf. Debele et al. 2019). Also, regional documentation can be useful and be a missing link between local and global data pools as shown by the new NBS Bangladesh community of practice (http://www.nbsbangladesh.info/case-studies/). This database opened after our initial data pool collection, indicating that the field of NBS data pool creation is highly dynamic.

4.2 NBS data pools to improve knowledge transfer

The analysis of the 21 databases enables us to elaborate on the necessary data that should be present in data pools. Currently, data pools on NBS case studies focus on describing the location where NBS are implemented as well as the particular NBS measures. The co-benefits of NBS are highlighted in some data pools because of their importance in the two popular NBS definitions from the EU (European Commission 2015) and IUCN (Cohen-Shacham et al. 2016) and because they remain the subject of most research on NBS (Short et al. 2019, Song et al. 2019, Ferreira et al. 2020).

When data pools contain information about governance issues, then it is in terms of the stakeholders involved, the financing of the projects, the timeframe and the responsible project partners. We suggest that it would be necessary to provide more concrete and useful information on institutions, actors and their interplay, financing mechanisms and societal benefits. So far, concerning financing, the overall amount of costs and the main financer should be mentioned to support knowledge transfer on NBS governance. It is worthy to note that the institutional setting or the involved

stakeholders are rarely mentioned. Stakeholder interactions and decision-making processes are not mentioned anywhere. Also, considering the vast research that exists on societal benefits (ecosystem services) and NBS, such as urban green infrastructure, the presented information in databases remains, for the most part, vague and superficial. For example, while the ecosystem service itself may be mentioned, i.e., water retention, it is usually not assessed or presented clearly so that it may serve as evidence or tangible data.

Consequently, according to our understanding, a more efficient record in a NBS data pool should include the following attributes, which are systematically populated and curated:

- site description including a map,
- governance models,
- solution including type, description, size, picture and supplementary material, e.g. poster,
- challenges, type of risk and exposure,
- scales (spatial, temporal, administrative),
- ecosystem processes and services including a link to existing ecosystem services assessment platforms
- institutions in charge and participating in planning, implementation, and monitoring,
- stakeholder constellations,
- financing instruments including cost and financing mechanisms and
- societal benefits and conflicts.

The attributes are not ranked according to importance as this would be a subjective decision.

Regarding ecosystem services as an important part of the NBS concept, a clear assessment needs to be presented. For governance issues, it would be necessary to describe the organisational structure (actor types and decision-making structures) for the planning and the implementation process of NBS, the coordination (actors and procedures) and participation (participation type, actors involved, and intensity of participatory process), as well as the institutional setting within which the case is embedded (including institutional interplay mechanisms). For financing, we would include the project budget/costs, financing sources, financing mechanisms, financing institutions, financing mechanism workload and mechanism financing amount organized by main funding schemes. We also see the need to provide information on property rights like the land ownership structure and land transactions.

NBS databases in comparison, such as the NBS Atlas on the Naturvation website as a positive example, provide more structured and detailed information on governance and financing. The database records (case studies) have attributes for governance models, each with several pre-defined options for values. This allows a user to filter records by these values, e.g. selecting only records with financing out of public budget or a governmental management.[3] Similarly, case studies can be filtered by initiating organisation. Additional governance information is displayed directly on the page of an individual case study but is not available for a filtered search. This information includes participatory approaches / community involvement and details on the roles of the organisations involved in the project. Each case study additionally specifies whether it was implemented in response to (i) an EU policy or strategy, (ii) a national policy or strategy or (iii) a local policy or strategy. While the standardized values for the governance model attributes improve filtration of records, the current

[3] The complete list of attributed values: earmarked public budget, direct funding or subsidies, loan, equity funding (investment shares), asset-backed funding (e.g. leasing), tax exemption, donations, membership fees, other.

trade-off is a lack of qualitative description to accompany those attributes. Moreover, attribute values are often not populated, and the quality of information remains relatively poor (see Table 2).

For web catalogues, the RECONECT project is a good example that demonstrates progress to provide information on governance and financing aspects. On this website, the category implementation includes five related subthemes: 1) Description of nature-based solution and works within RECONECT; 2) Benefits from Nature-based Solution; 3) Key Actors; 4) Key Innovation and potential for upscaling; 5) Demonstrator Poster (PDF).

Having accurate collected and presented information in NBS data pools will greatly help the science-practice community on NBS. For scientific research, studies based on data pool analysis may enable experts to generate guidelines for success in NBS implementation (Zingraff-Hamed et al. 2020, accepted)(Zingraff-Hamed et al. 2020, accepted), while practitioners may learn about the reasons why successful demonstrator cases are successful. Improvements in knowledge in both science and practice will help to overcome implementation hurdles for NBS. Therefore, for further database construction and research on NBS cases, we recommend the following:

1. Be more precise on important aspects of the NBS definition and provide information beyond the case study site description, the challenges and the solution, namely on ecosystem processes and services, governance and financing structures, cost-effectiveness, scale, co-benefits and time horizon.
2. Require information on governance and on financing models in case study descriptions of NBS.

3. Apply rigorous conventions for data entry and record creation at different levels, .e.g. by incentivizing and monitoring project partners or by promoting an overall agreement in terms of global standards.

This call to action in future research and science communication will make the upscaling, comparisons and sharing of lessons learned for NBS implementation easier.

The current practice of recording NBS best practice cases in project specific databases is insufficient to provide the fundamental data points necessary for effective knowledge transfer. It is critical to record and provide knowledge on NBS cases in overall databases independent of project funding and context. This, however, is a difficult, lengthy and a resource-intensive endeavour, since it requires standards for data recording and reporting across projects. Collating and aggregating information from project websites is insufficient as data is often patchy and of varying quality.

To increase the knowledge transfer potential of existing databases, future funding should be directed towards them to improve their quality. Additionally, the development of a common minimum standard for recording data on NBS cases in future EU-funded research projects would unleash the potential for building a coherent overall data pool on the foundation of the Oppla database. The currently released IUCN Global Standard for Nature-based Solutions could also be a starting point (IUCN 2020).

4.3. Limitations

Our study offers an overview on the international knowledge transfer potential of NBS. We assume that the systematic analysis draws a representative picture of the

online data pool landscape. However, the field is highly dynamic and we mentioned in the discussion that some data pools were published after our initial data pool collection. Also, the data pools that we screened are likely to complete their entries on an ongoing basis. Furthermore we did not consider data pools that did not contain information in English. Consequently we may have not found some important data pools documenting NBS in South America, Asia and Africa as well as data pools with a regional or national focus in the EU which are available in the respective country language and may therefore provide domestic stakeholders with valuable information. Due to our focus on the term nature-based solutions, data pools providing similar information but using a different wording, e.g. green-blue infrastructure (Hanson et al. 2020), or older data pools not connected to the new NBS terminology, could not be identified, such as Susdrain (https://www.susdrain.org/), which uses the term, sustainable drainage system (SuDS), amongst others. To tackle this language issue, recently a survey was launched on the Oppla website to try to identify a common language on the vast spectrum of NBS technologies (https://oppla.eu/nature-based-solutions-terminology-survey?pk_campaign=Outline).

Further, the method for assessing data quality of the paper can be refined. Calculating the overall mean value allows us to compare the data pools with these values. However, the number of well evaluated variables can vary between data pools with higher and lower mean values.

5. Conclusions

The objective of this study was to highlight whether online data pools collecting information on NBS case studies have the potential to effectively transfer that knowledge for further implementation and upscaling endeavours. In our analysis of 21 online data pools on NBS, we showed that they currently only have limited

potential to transfer valuable knowledge and expertise for upscaling and implementing NBS. This potential needs to be further unlocked by systematically recording and curating data and information and by including necessary information on the governance and financing aspects of NBS. This would allow researchers and practitioners to carry out necessary meta-analyses to produce large scale recommendations for NBS design and implementation.

As the concept of the NBS is still relatively new and many research projects are still ongoing, the knowledge on NBS will be gradually improved and expanded. At the moment, there is certainly a lack of data due to the lack of completed studies. But we can expect a natural positive trend, so to speak, due to the many projects and the high level of interest in the topic.

In summary, our research concludes that while the field of NBS knowledge pools in the form of online data pools is very dynamic and important for knowledge transfer, future funding programs should focus on improving the structure and information captured in NBS online data pools to leverage the experience and findings of previous case studies for overcoming hurdles in NBS implementation and for enabling successful upscaling of NBS.

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9. Author contributions

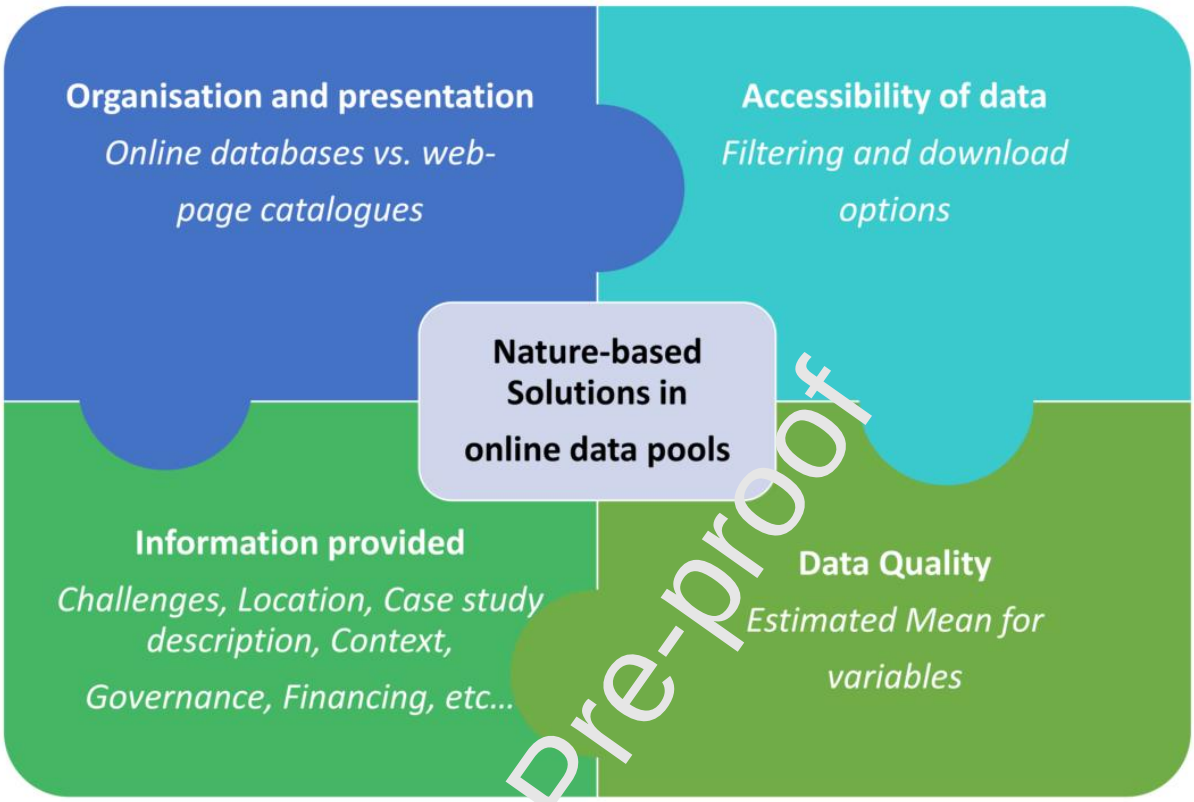
BS contributed to conceptualization; Data curation; Formal analysis, Methodology; Writing the original draft, reviewing and editing. AZH contributed to Conceptualization; Data curation; Formal analysis; Methodology; Visualization; Writing - original draft; Writing - review & editing. EO contributed to Conceptualization; Methodology; Validation; Writing - original draft; Writing - review & editing. JH contributed to Data curation; Writing - original draft; Formal analysis; Writing - review & editing. FH contributed to conceptualization; methodology and Writing: Review & Editing. CN contributed to conceptualization; methodology and Writing: Review & Editing. NJSS contributed to conceptualization and writing: Review & Editing.

Declaration of interests

☒ 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.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Graphical abstract



Highlights

- The majority of examined data pools contain merely basic and limited information
- They inform of settings and implemented measures offering a broad catalogue of NBS
- Key information on ecosystem processes, governance and financing is omitted
- The missing data hinder case comparison and potential cross-fertilization processes
- Cases are mostly situated in the EU, other parts of the world are underrepresented

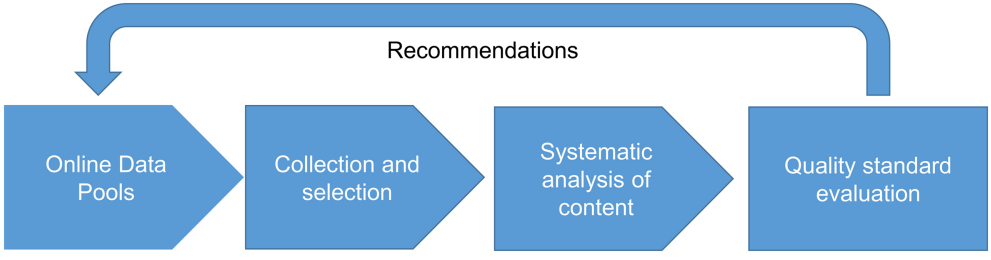

Recommendations
Online Data Pools
Collection and selection
Systematic analysis of content
Quality standard evaluation

Figure 1

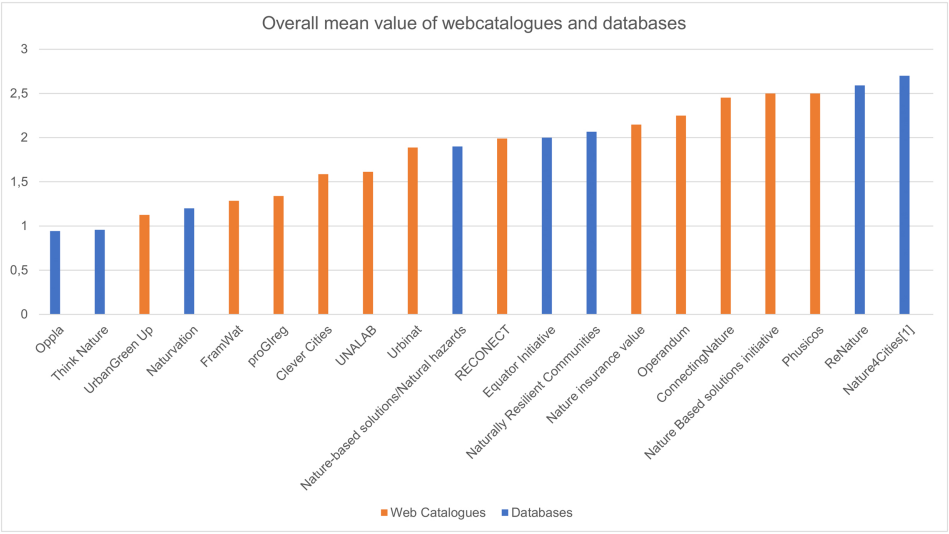

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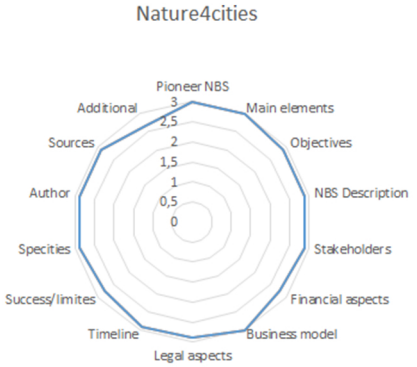
Figure 2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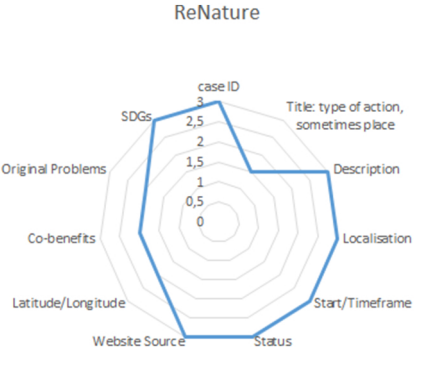
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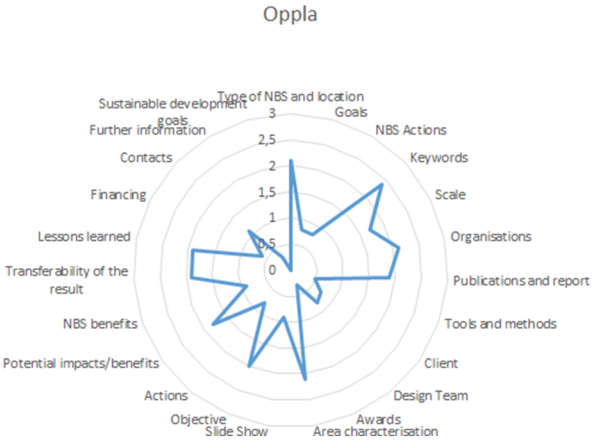
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Potential impacts/benefits
NBS benefits
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Lessons learned
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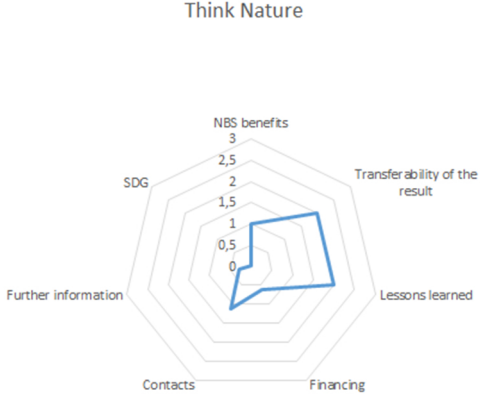
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Figure 3